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Ballistic Evaluation of the Under-Barrel Tactical Paint Ball System

by David H. Lyon

ARL-TR-1899 March 1999

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Army Research Laboratory
Aberdeen Proving Ground, MD 21005-5066

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Ballistic Evaluation of the Under-Barrel Tactical Paint Ball System

David H. Lyon
Weapons and Materials Research Directorate, ARL

Abstract

This report contains data obtained while conducting a test of the Under-Barrel Tactical Paint Ball System (UTPBS). This testing was conducted by the U.S. Army Research Laboratory (ARL) upon the request of both the U.S. Army Armament Research, Development, and Engineering Center (ARDEC) and user representatives. The UTPBS device attaches under the barrel of either the M16 rifle or M4 carbine, similar to an M203. It consists of a trigger group and a central launch tube, which is surrounded by five rotating magazine tubes. A compressed gas bottle is located coaxial to the launch tube and supplies high-pressure gas for operation of the device. Five different types of projectiles were evaluated with the launcher. These were based upon a spherical, ruggedized paint ball with a hard plastic shell and various fills that contained bismuth powder and a combination of paint or water. The system was fired for target impact dispersion, launch dynamics, aerodynamics, and clay penetration. The ability of the weapon to target and hit a triple silhouette at 100 m was almost zero. To isolate the sources of trajectory deviation, a launch dynamics test was performed. A combination of x-rays and spark shadowgraphs revealed large transverse displacements immediately following launch. The case of this deviation was related to the shifting of the bismuth powder inside the projectile, thereby creating a mass asymmetry.

Acknowledgments

The author would like to thank Brendan Patton and Donald McClellan, both of the Aerodynamics Experimental Facility, for their always professional support. Thanks also goes out to the range technicians operating the Transonic Experimental Facility for equally proficient efforts.

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1. Introduction

The Joint Non-Lethal Weapons Directorate, in seeking solutions to a specific set of user requirements, procured a contractor-designed device referred to as the Under-Barrel Tactical Paint Ball System (UTPBS). This report contains data obtained during evaluation testing of the UTPBS. This test series was conducted by the U.S. Army Research Laboratory (ARL), located at Aberdeen Proving Ground, MD, upon the request of both the U.S. Army Armament Research, Development, and Engineering Center (ARDEC) and the U.S. Army Infantry Command (USAIC) representatives. Two ARL test sites were utilized to collect data—the Aerodynamics Experimental Facility and the Transonic Range Experimental Facility. Several critical performance aspects of the systems were evaluated to include target impact dispersion, launch dynamics, projectile aerodynamics, and basic weapon function.

The UTPBS attaches under the barrel of either the M4 carbine or the M16A2 rifle. It consists of a central launch barrel surrounded by five rotating magazine tubes, situated forward of the trigger group. A compressed gas bottle is located coaxial to the launch tube and is retained, via threads, to a pressure regulator. The regulator, in turn, supplies gas to the bolt mechanism. A limited range of velocity adjustment can be achieved by turning an internal regulator component with a hex key; however, the instructions contain no guidelines relating the amount of regulator adjustment to velocity deviation. The trigger group contains a safety, which blocks movement of the trigger.

One launcher was supplied by ARDEC (SN00009) along with five different types of projectiles. Table 1 provides a brief description of each ammunition type and quantity shipped. The shipping tubes themselves were designed to accommodate up to 10 projectiles. The mass of each individual projectile was determined, using an electronic scale, and then each projectile's position and tube number were recorded. The individual results are contained within the target impact tables of Appendix A.

Table 1. UTPBS Ammunition Description

Designation	Description	Projectile Mass (g)	Quantity
Type No. 1	Clear plastic shell with Bismuth powder, no liquid.	6 (nominal)	90
Type No. 2	Clear plastic shell with Bismuth powder in yellow paint.	6 (nominal)	100
Type No. 3	Clear plastic shell with Bismuth powder in yellow paint.	8 (nominal)	100
Type No. 4	Clear plastic shell with Bismuth powder in water.	8 (nominal)	100
Type No. 5	Clear plastic shell with Bismuth powder in water.	6 (nominal)	100

The test plan contained several phases including (1) target impact dispersion, (2) launch disturbance and aerodynamics, and (3) clay penetration. The UTPBS launcher was mounted under an M16A1 upper receiver, which was then fixed in a Frankford Arsenal gun mount. It was necessary to force the forward clamp of the UTPBS under the M16A1 gas tube, pushing the tube upward, to allow the clamp to squeeze between the tube and M16 barrel. Due to availability, the compressed gas bottles were charged with dry nitrogen to a pressure of 15.17 MPa (2,200 lb_f/in^2). A maximum of 45 shots were fired from any one bottle before it was replaced with a fully charged bottle. Before recharging, a pressure reading was taken on all bottles. Each bottle was found to contain a minimum pressure of 9.62 MPa (1,400 $lb_f/in^{2)}$). The manufacturer recommended a launch velocity of 76.2 m/s (250 ft/s) for all ammunition types, although, as later detailed, this was difficult to attain.

2. Target Impact Dispersion (TID)

The TID test included ranges from 15 m out to 100 m. The targets for the 15-m, 30-m, and 45-m ranges consisted of a 4-ft × 8-ft sheet of sheathing (Georgia Pacific), 12.5 mm (1/2 in) thick. This material consists of pressed cellulose fibers and is significantly softer than plywood. Centered on the sheet was the outline of an E-type silhouette, complete with a crosshair at the center of mass

(Figure 1). The silhouette measured 0.49 m wide by 1 m high. For the 60-m, 75-m, and 100-m ranges, three side-by-side E-type silhouettes were outlined on two sheets of sheathing (Figure 2). Additional sheets were added to each side and along the top of the target with increased range, eventually resulting in a target that was 16 ft square, in an attempt to capture all impacts. The weapon was sighted using a Wild tactical boresight. Since the UTPBS is not of a standard barrel dimension, a boresight adaptor was fabricated for use with the UTPBS barrel. In addition, a Weibel 680 Doppler radar was used to record velocity data for a sampling of rounds at each range. At the 15-m range, no superelevation was added; the weapon was boresighted directly at the cross. For all other ranges, varying amounts of superelevation were added; however, no azimuth corrections were necessary. The level of elevation was computed in advance utilizing a 2 degree-of-freedom ballistic trajectory code with the appropriate projectile mass and range. However, when the actual velocities for the 8-g projectiles fell below the desired 76.2 m/s, the slightly higher elevations for the 6-g projectiles were used in an effort to compensate. The weapon was set to the predicted elevation using a standard gunner's quadrant.

The initial test plan called for a 15-round group of each ammunition type to be fired at each range. This would yield a dispersion value with relatively high confidence. However, after a gun malfunction combined with a leakage problem during velocity adjustments, some of the further testing had to be reduced to 10-round groups. The TID sheets of Appendix A contain individual data for each round including projectile mass, launch velocity, and impact coordinates. Table 2 contains a summary of the target hits, expressed as a percentage, for each ammunition type at each range.

2.1 15-m Summary. All three types of 6-g projectiles were launched with an average muzzle velocity that ranged from 74.9 m/s (246 ft/s) to 77.1 m/s (253 ft/s). This same regulator setting resulted in a muzzle velocity of approximately 64.0 m/s (210 ft/s) for the 8-g projectiles. When an adjustment of the regulator was attempted, a gas leak occurred. This was apparent from the hissing sound of gas escaping from the regulator area. Therefore, the regulator was returned to its original setting, where the leak stopped, and the remainder of the 8-g projectiles were fired. Very few rounds missed the silhouette, with three of the five types achieving 100%. The gun was elevated at 28.4 mils and was aimed at the center of mass.

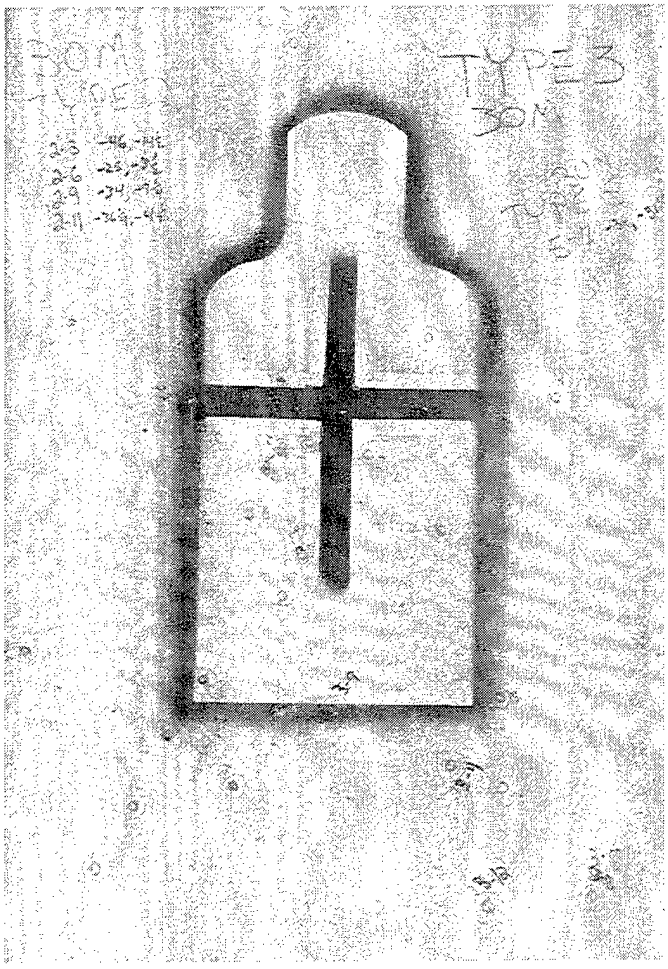

Figure 1. Shorter Range Target, One E-Type Silhouette Outline on 4-ft × 8-ft Sheathing.

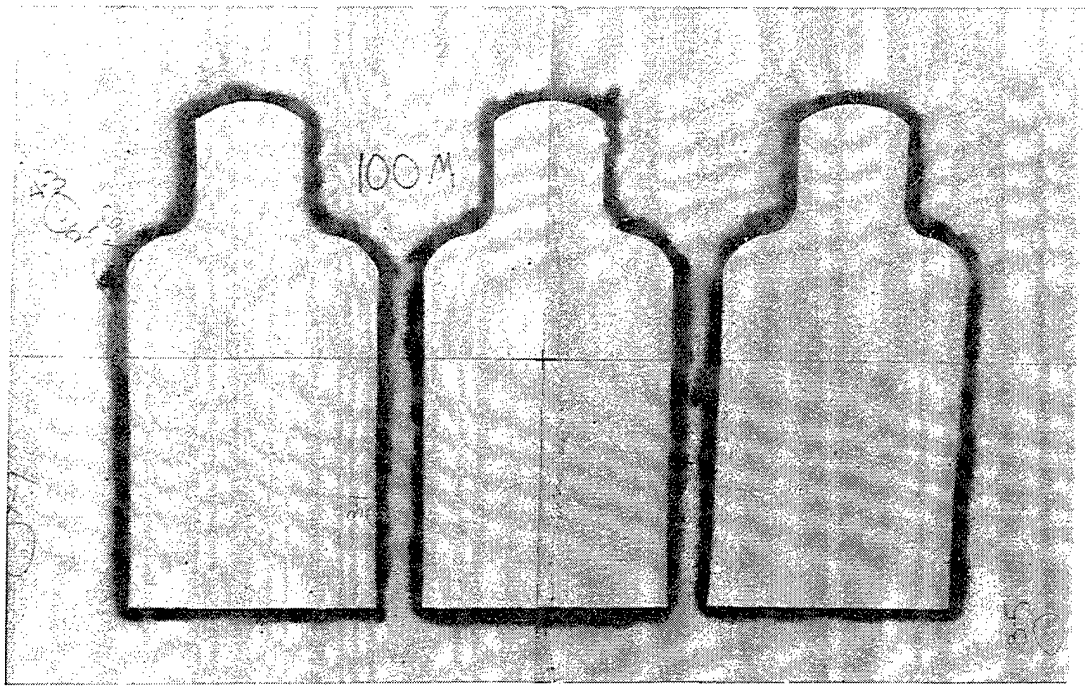

Figure 2. Longer Range Target, Three E-type Silhouettes on 8-ft-Square Target.

Table 2. Summary of Target Impact Data

Range (m)	Hits for Type No. 1 (%)	Hits for Type No. 2 (%)	Hits for Type No. 3 (%)	Hits for Type No. 4 (%)	Hits for Type No. 5 (%)
15	93.3	80	100	100	100
30	66.7	20	33.3	60	73.3
45	26.7	13.3	26.7	33.3	46.7
Target changed from single silhouette to triple silhouette.					
60	20	6.7	13.3	6.7	0
75	0	30	20	30	20
100	0	0	10	0	0

2.2 30-m Summary. Again, the 6-g projectiles were launched at approximately 76.2 m/s (250 ft/s), while the muzzle velocity for the 8-g projectiles was significantly less. Another attempt to increase the velocity was made, and by "tweaking" the regulator, an average muzzle velocity in the 67.1-m/s (220 ft/s) range was achieved without any leaks. At this range, the number of silhouette misses increased significantly. The gun was elevated to a quadrant reading of 45.27 mils for all round types. This elevation was below optimum for the 8-g projectiles, due to their lower than expected launch velocities.

2.3 45-m Summary. Velocity results were similar to previous ranges. The gun was elevated to a quadrant reading of 50.84 mils for all rounds. The percentage of hits further decreased.

2.4 60-m Summary. To minimize the number of velocity adjustments at each range, ammunition type nos. 1, 2, and 5 were fired first. In the middle of firing type no. 5, the weapon safety malfunctioned and was physically stuck in the "FIRE" position. This caused a stoppage of the test. The manufacturer was contacted and arrived to conduct repairs to both the safety and the regulator internal workings. The overpressure relief mechanism was adjusted to provide enough working pressure to launch an 8-g projectile at 76.2 m/s. During the firing of type no. 3 projectiles, the velocities were quite low, and a regulator adjustment was attempted. However, the regulator could not be adjusted; instead, the internal regulator workings screwed out. This resulted in a

stoppage of testing and reassembly of the regulator. From 60 m on out, the target was changed from a single silhouette to three E-type silhouettes arranged in a side-by-side configuration. The gun was elevated to a quadrant reading of 69.1 mils. Even with the three-silhouette target, the number of hits decreased regardless of ammunition type.

2.5 75-m Summary. The velocity for type no. 1 projectiles was below 250 ft/s, and a regulator adjustment was attempted. Again, the regulator would not allow such an adjustment without disassembly. The gun was elevated to a quadrant reading of 101.0 mils. The number of target hits actually increased for four of the ammunition types. However, with only one 10-round group of each type, the statistical significance of these increases is in question.

2.6 100-m Summary. During these groups, velocity adjustment was achieved through the use of the hex key and did not require disassembly of the regulator. However, the amount of adjustment only allowed the 8-g projectiles to achieve a launch velocity of approximately 72.2 m/s (237 ft/s), as opposed to 76.2 m/s. At the beginning of the type no. 4 group, one projectile burst in the barrel. The barrel was cleaned before proceeding. The gun was elevated to a quadrant reading of 151.0 mils. The number of hits at this range was zero for type nos. 1, 2, 4, and 5. Projectile type no. 3 scored 1 hit out of 10.

As mentioned, a Doppler radar was used to obtain velocity-vs.-time data. These data were then fit using a first-order polynomial, and the results were converted into a velocity-vs.-distance format. Radar traces were attempted for at least one round from each group. However, the longer ranges proved difficult due to the significant trajectory arc. Several representative traces are included in Appendix B.

3. Launch Disturbance and Aerodynamics

In order to assess the initial launch disturbance imparted to the projectile, a series of firings was conducted through the ARL Aerodynamics Experimental Facility. This facility utilizes spark shadowgraph stations to record the projectile location at numerous downrange distances. In addition,

flash x-rays were incorporated near the launcher muzzle. This method employs a double-flash technique, along with a fiducial wire and beads, which are suspended precisely along the line of fire. The x-ray cassettes are flashed once with this wire in place, and then the wire is removed and the actual round fired, during which time the x-rays are flashed a second time. The result is a single film on which both the fiducial wire and projectile appear. With this calibration directly on the film, measurements of the projectile velocity and deviation from the intended line of flight, referred to as either drift or swerve, are both simple and accurate. In addition, since the projectile was a plastic shell with metal powder, the use of soft x-ray tubes revealed the position and distribution of bismuth inside the projectile.

The x-ray heads were positioned to observe both the vertical and horizontal planes simultaneously, in an orthogonal configuration. A series of six x-ray stations was employed to provide detailed coverage during the first several meters of flight. They were located at the following distances from the UTPBS muzzle: 2.06 cm, 37.63 cm, 75.73 cm, 113.83 cm, 151.29 cm, and 189.39 cm. The data extracted from these x-rays include the exact downrange location as well as the displacement, or drift, from the original line of fire. The drift data are contained in Table 3, while these same data are plotted in Figures 3–7 to allow a relative comparison. Lastly, to determine the orientation of bismuth powder while the projectile was still in-bore, an x-ray was positioned to observe the projectile by "looking through" the barrel. Appendix C contains contact prints, obtained using this setup, for type no. 1 and type no. 2 projectiles. These reveal that, near the muzzle, the bismuth powder is located in the lower rear of the projectile. They also indicate that there exists a slight difference in bismuth position between the dry interior and the paint-filled interior, suggesting a viscosity effect. Appendix D contains a sequence of the first three vertical x-ray stations for a type no. 2 projectile. These reveal rather violent movement of the powder within the projectile. Between stations 1 and 2, the powder has shifted predominantly from the bottom to the front, while in station 3 it has moved to the top-rear, with particles shifting in a turbulent manner.

Following the x-ray stations, the projectile was photographed by a series of orthogonal spark shadowgraph stations. These stations are spaced every 2–3 ft along nearly 100 m of instrumented range length. The data from this facility allowed a very precise determination of both drag and x, y position. Several shadowgraph photos are included in Appendix E.

Table 3. Transverse Displacement Data Extracted From Muzzle X-rays

Round No.	Displacement at Each X-ray Station											
	Station 1		Station 2		Station 3		Station 4		Station 5		Station 6	
	Vert. (cm)	Horiz. (cm)	Vert. (cm)	Horiz. (cm)	Vert. (cm)	Horiz. (cm)	Vert. (cm)	Horiz. (cm)	Vert. (cm)	Horiz. (cm)	Vert. (cm)	Horiz. (cm)
21583	-.07	NR[a]	-.28	-.05	-.45	-.20	-.74	-.29	-1.02	-.38	-1.29	-.46
21584	0	NR[a]	-.90	-.06	-1.42	-.06	-1.81	.06	-2.32	.21	-3.16	.26
21585	-.04	NR[a]	-.41	-.11	-.90	-.25	NM[b]	-.38	-1.57	-.53	NM[b]	-.65
21586	-.02	NR[a]	-.03	.25	-.36	.48	-.46	.41	-.46	.47	NM[b]	.59
21587	-.09	NR[a]	-.12	-.08	-.38	-.13	NM[b]	-.20	-1.20	-.31	-1.48	-.45

[a] NR = Not readable due to interference of M16A1 barrel.

[b] NM = No measurement possible.

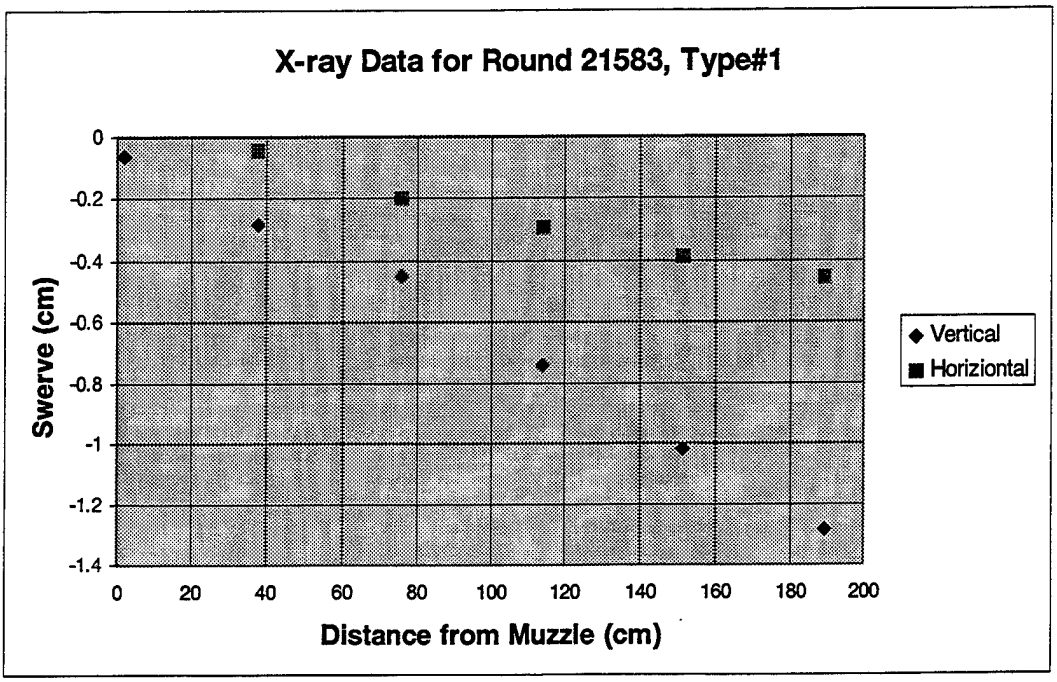

Figure 3. Orthogonal X-ray Data for Type No. 1 Projectile (Round 21583).

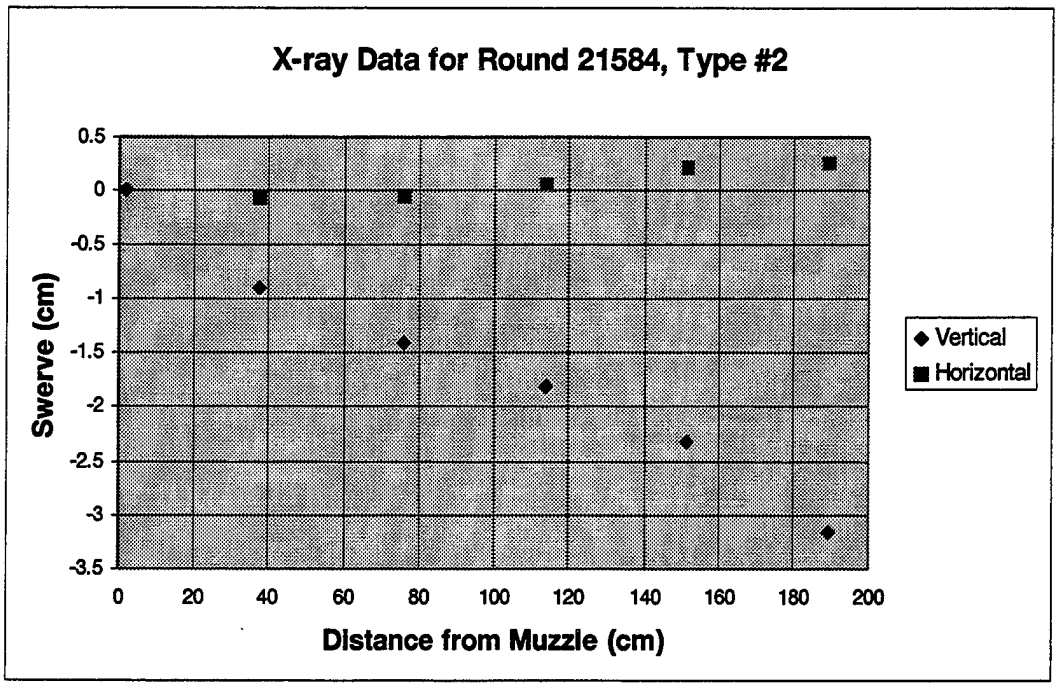

Figure 4. Orthogonal X-ray Data for Type No. 2 Projectile (Round 21584).

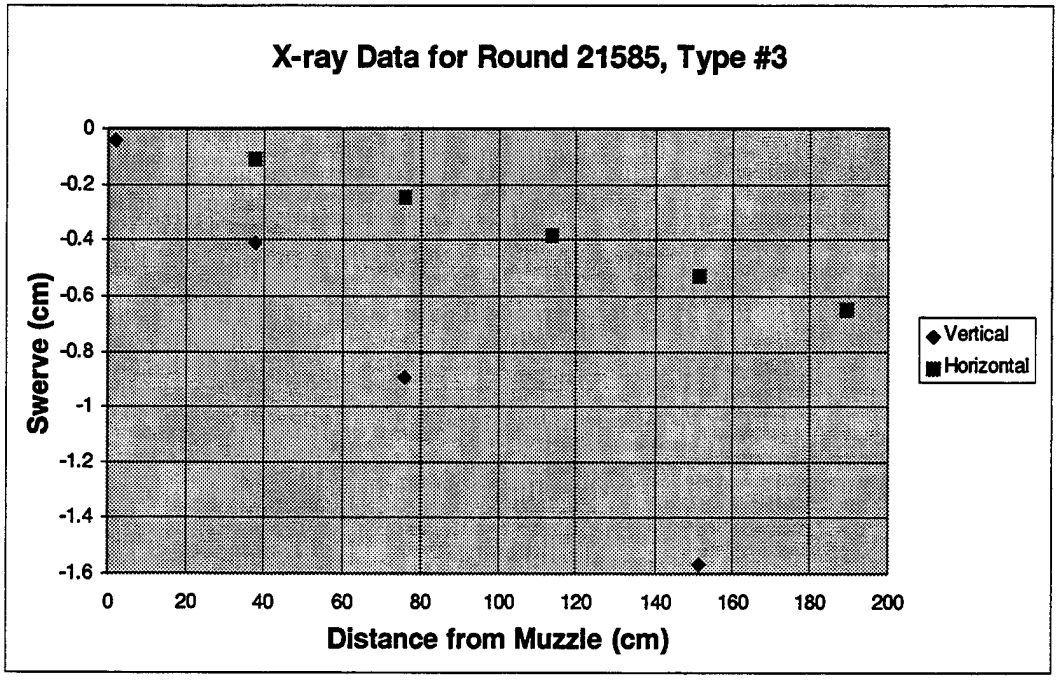

Figure 5. Orthogonal X-ray Data for Type No. 3 Projectile (Round 21585).

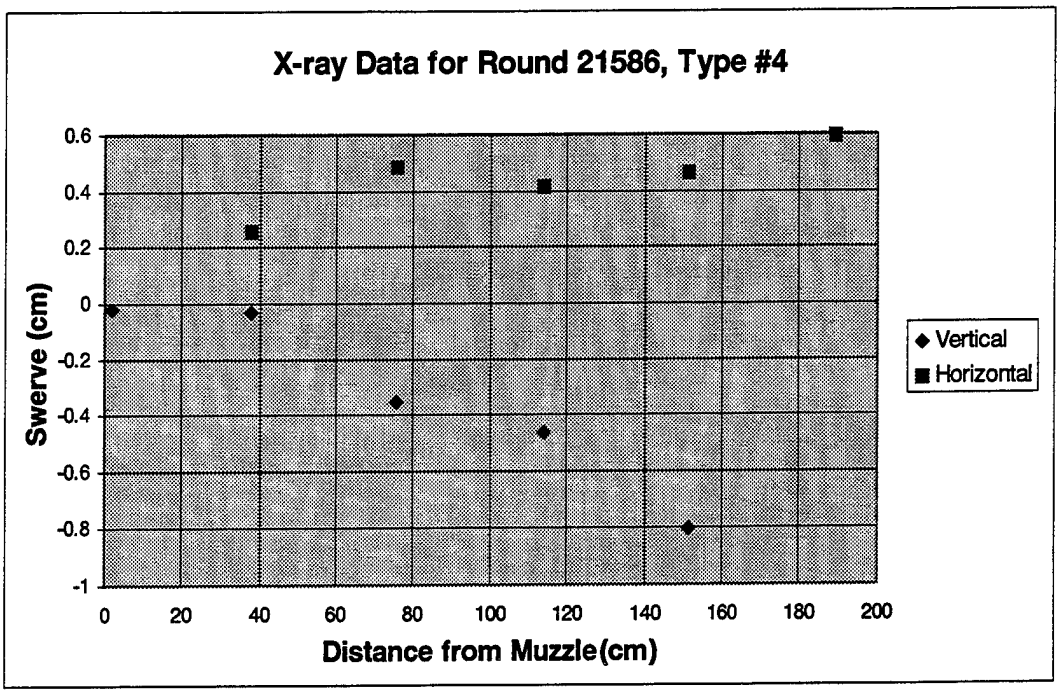

Figure 6. Orthogonal X-ray Data for Type No. 4 Projectile (Round 21586).

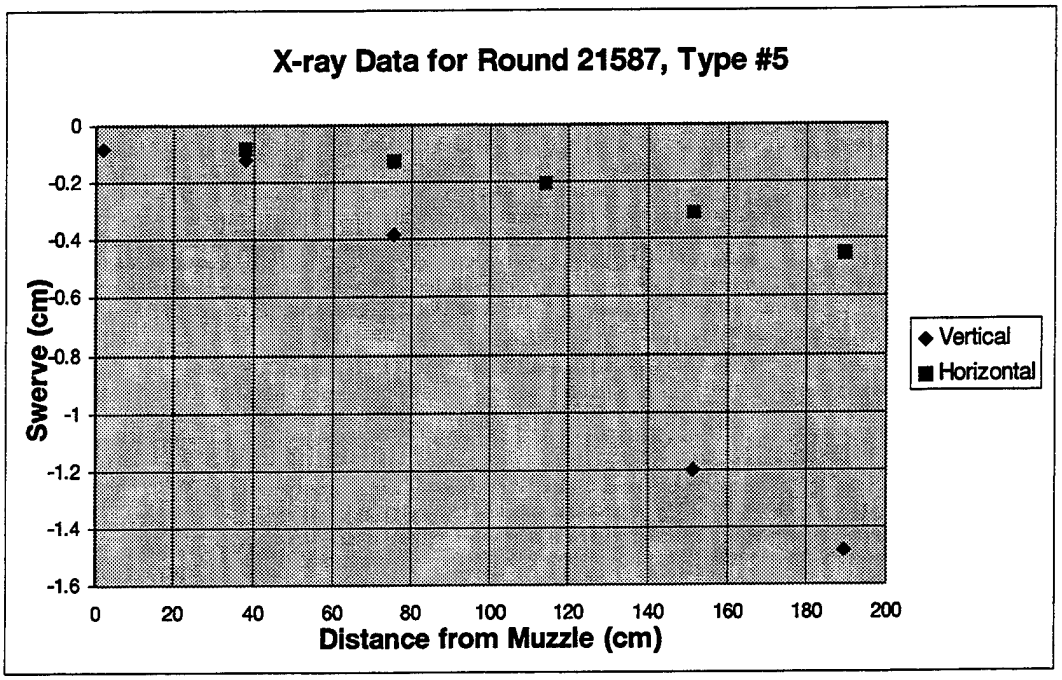

Figure 7. Orthogonal X-ray Data for Type No. 5 Projectile (Round 21587).

The reduced Aerodynamics Facility data provided the input necessary to compute trajectories using a ballistic simulation program. The drag coefficients were further verified by comparison with the radar data. The series of plots in Appendix F illustrates the trajectory of both the 6-g and 8-g projectiles at ranges of 30 m, 75 m, and 100 m, respectively. The last plot depicts the velocity decay to a range of 100 m and the difference between a 6-g and an 8-g projectile.

4. Clay Penetration

In an attempt to characterize the potential injury levels imparted by these projectiles, a series of firings was conducted using a modification to the National Institute of Justice standard for soft body armor.[1] Typically, a sample of body armor is placed in contact with the clay, and then the threat munition is fired at this configuration. Using this standard, a cavity depth of 44 mm or deeper suggests a potentially fatal injury. However, since the targets for nonlethal munitions are generally not armored, the body armor was removed and the clay impacted directly by the munition. This modification has been used previously and serves as a point of relative comparison with other nonlethal munitions. The experimental setup included the UTPBS launcher in a hard mount at a fixed distance from the clay target. A pair of velocity screens measured the impact velocity while a high-speed video camera recorded the impact event. Afterward, the cavity depth and diameter were measured, and the target was prepared for the following round. Impacts at various ranges were simulated by varying the impact velocity. Starting with full muzzle velocity, the regulator was incrementally adjusted to decrease the impact velocity down to 37.5 m/s (123 ft/s). The results are summarized in Table 4 and plotted in Figure 8 according to nominal projectile mass.

The plot depicts a linear trend, over the range of data, although there is considerable scatter at the higher velocities. It also reveals that there is no significant penetration difference between the 6-g and 8-g projectiles impacting at similar velocities. Such a result was not expected due to the increased impact energy of the heavier projectiles. This result may be related to the total volume of

[1] National Institute of Justice. "Ballistic Resistance of Body Armor." NIJ Standard 0101.03, Washington, DC, April 1987.

Table 4. Results From Clay Penetration Test

Projectile Type No.	Projectile ID (tube, serial no.)	Projectile Mass (g)	Impact Velocity (m/s)	Cavity Depth (mm)	Cavity Diameter (mm)	Video Coverage[a]
3	9,9	8.13	76.2	35.8	19.8	Yes
3	9,10	8.04	76.2	34.5	20.1	No
3	10,1	8.10	73.8	30.0	24.1	Yes
3	10,2	7.98	73.5	36.1	25.9	Yes
3	10,3	8.09	72.5	35.6	24.9	Yes
3	10,5	8.01	69.2	35.1	22.9	Yes
3	10,6	8.10	71.3	37.6	22.4	Yes
3	10,7	8.09	67.7	34.8	22.6	Yes
3	10,8	8.13	68.0	35.1	21.8	Yes
3	10,9	8.08	66.8	26.7	21.3	Yes
3	10,10	8.10	ERROR	21.1	18.5	Yes
4	10,1	8.13	43.9	20.8	20.1	Yes
4	10,2	8.14	37.5	15.0	17.3	Yes
4	10,3	8.12	38.7	17.8	17.5	Yes
1	9,3	6.09	49.7	23.1	17.3	Yes
1	9,4	6.09	50.0	20.3	17.3	Yes
1	9,5	6.09	77.1	45.2	23.9	Yes
2	9,2	6.02	78.9	39.1	25.4	Yes
2	9,3	6.02	78.9	34.3	27.7	Yes
2	9,4	6.02	62.2	27.2	24.1	Yes
2	9,5	6.01	52.4	23.6	17.3	Yes

[a] At 4,500 frames/s.

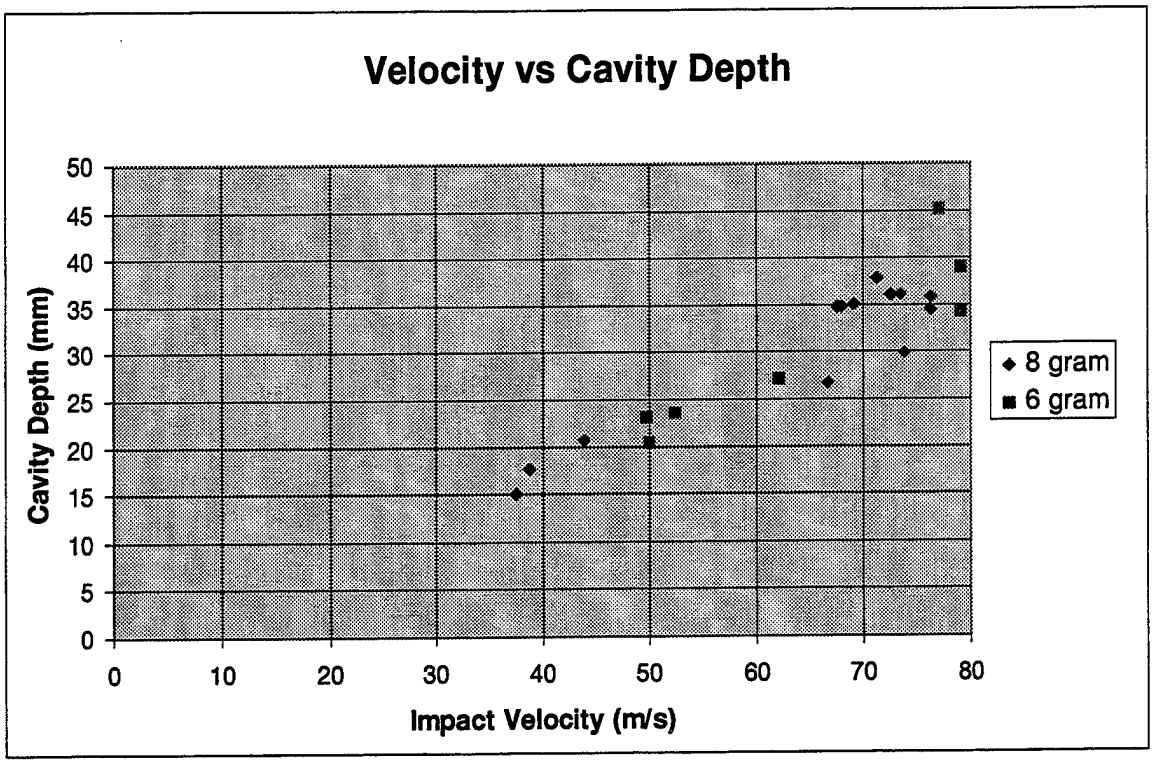

Figure 8. Clay Penetration Results Plotted as a Function of Velocity vs. Depth.

the hole, and not merely a function of the maximum cavity depth. It also may be a function of the manner in which the projectile fractures and deposits energy in the clay.

5. Summary and Conclusions

The primary test objective was to determine at what range the UTPBS was able to consistently hit either a single or triple silhouette target. To obtain this data, a TID test was conducted at various ranges. In addition, several performance aspects, including projectile launch dynamics, projectile aerodynamics, and basic weapon function, were also evaluated. The ballistic characteristics were investigated using a combination of experimental techniques. These included velocity screens, x-rays, spark shadowgraphs, Doppler radar, and clay penetration. TID was also recorded at various ranges

with each of five different ammunition types. The UTPBS experienced a weapon safety malfunction in addition to an inability to adjust the velocity without the regulator leaking. The manufacturer was able to fix the safety and adjust the regulator, although it remained difficult to adjust and had to be disassembled several times. The UTPBS was able to consistently hit an E-type silhouette at both 15 m and 30 m; beyond those ranges the percentage of hits dropped significantly. The system ability to target and hit a triple-wide silhouette, at 100 m, was virtually zero. In addition, there is no way of determining how much pressure was available in the compressed gas tank.

The combination of x-ray and spark shadowgraph data shows that the UTPBS projectiles can experience significant transverse displacements (swerve) immediately following launch. The severity of this deviation is a function of the bismuth powder shifting inside the projectile, creating a mass asymmetry, or unbalance. The relatively high-viscosity liquid paint appears to damp this effect somewhat; however, significant deviations were still observed. The projectile spin imparted by the slow-twist rifling appears to be unable to compensate for these effects. The large swerve was further exasperated by a boundary-layer transition point that wandered over the forebody of the projectile. This produced a random flow separation and vortex shedding, which resulted in asymmetric aerodynamic forces.

Appendix A:

Target Impact Data Sheets

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Table A-1. UTPBS Test Data (15-m Impact Dispersion), Single E-Type Silhouette

ID No.	Project Type No.	Tube No., Serial No.	Mass (g)	M_v (ft/s)	Impact Location (Relative to Center of Mass)		
					Horizontal (in)	Vertical (in)	Hit Silhouette
Test Date: 3/19/98							
1-1	1	1,3	6.12	254	-7.25	-3.5	Yes
1-2	1	1,4	6.08	251	-4.25	-10	Yes
1-3	1	1,5	6.08	247	2	-7	Yes
1-4	1	1,6	6.07	245	3	-12.5	Yes
1-5	1	1,7	6.08	244	0.5	-8.5	Yes
1-6	1	1,8	6.07	245	5	-11	Yes
1-7	1	1,9	6.07	245	4.75	-19	Yes
1-8	1	1,10	6.11	244	5	-6	Yes
1-9	1	2,1	6.09	247	-1.25	-12.5	Yes
1-10	1	2,2	6.1	242	-4.75	-8.5	Yes
1-11	1	2,3	6.1	246	1.75	10.25	Yes
1-12	1	2,4	6.06	243	6.25	-3.5	Yes
1-13	1	2,5	6.06	247	1	-8.75	Yes
1-14	1	2,6	6.07	249	8.5	-22	No
1-15	1	2,7	6.07	247	7.5	-12	Yes
Average			6.08	246.40			
Std Dev			0.02	3.11			
Test Date: 3/19/98							
2-1	2	1,1	6	255	-1.5	-9	Yes
2-2	2	1,2	6.01	252	2.25	-12	Yes
2-3	2	1,3	6.03	252	2.25	-15	Yes
2-4	2	1,4	6.04	252	0.75	-12	Yes
2-5	2	1,5	6.03	253	8.5	-13.5	No
2-6	2	1,6	6.04	252	2.5	-10.5	Yes
2-7	2	1,7	6.03	253	8.875	-11	No
2-8	2	1,8	6.03	253	-7.5	-9.25	Yes
2-9	2	1,9	6.04	253	1.25	-13.375	Yes
2-10	2	1,10	6.03	253	-7.375	-10	Yes
2-11	2	2,1	6.02	252	17.25	-14.25	No
2-12	2	2,2	6.02	253	1.5	-11.875	Yes
2-13	2	2,3	6.02	250	-3.25	-9.75	Yes

NOTE: Barrel boresighted directly at target center of mass, Q.E. = 28.4 mils (1.60°).

Table A-1. UTPBS Test Data (15-m Impact Dispersion), Single E-Type Silhouette (continued)

ID No.	Project Type No.	Tube No., Serial No.	Mass (g)	M_v (ft/s)	Impact Location (Relative to Center of Mass)		
					Horizontal (in)	Vertical (in)	Hit Silhouette
2-14	2	2,4	6.02	256	2.25	-12	Yes
2-15	2	2,5	6.08	256	3.25	-8.75	Yes
Average			6.03	253.00			
Std Dev			0.02	1.60			
Test Date: 3/19/98							
3-1	3	1,2	8.05	214	Not Recorded	Not Recorded	Yes
3-2	3	1,3	8.06	209	-5.5	-15.5	Yes
3-3	3	1,4	8.11	207	-2	-15.5	Yes
3-4	3	1,5	8.1	207	-1.5	-18.5	Yes
3-5	3	1,6	8.19	202	1.75	-16.25	Yes
2-6	3	1,7	8.1	210	-4.5	-16.25	Yes
3-7	3	1,8	8.08	209	5	-19	Yes
3-8	3	1,9	8.05	208	-3	-18	Yes
3-9	3	1,10	8.05	214	1	-17.5	Yes
3-10	3	2,1	8.12	210	-6.75	-17	Yes
3-11	3	2,2	8.02	210	-6.25	-14.25	Yes
3-12	3	2,3	8.1	209	-4	-13.5	Yes
3-13	3	2,4	8.12	210	-4	-13.5	Yes
3-14	3	2,5	8.08	212	3.875	-19	Yes
3-15	3	2,6	8.07	213	-8.25	-14	Yes
Average			8.09	209.60			
Std Dev			0.04	3.07			
Test Date: 3/19/98							
4-1	4	1,2	8.12	215	-4.5	-14.5	Yes
4-2	4	1,3	8.08	215	-0.75	-13	Yes
4-3	4	1,4	8.1	206	-5	-16.375	Yes
4-4	4	1,5	8.13	209	-2.25	-15.25	Yes
4-5	4	1,6	8.12	210	-1.75	-15.125	Yes
4-6	4	1,7	8.12	215	4	-13.375	Yes
4-7	4	1,8	8.16	211	0.75	-13	Yes
4-8	4	1,9	8.11	210	7.5	-15	Yes
4-9	4	1,10	8.1	211	8	-13	Yes

NOTE: Barrel boresighted directly at target center of mass, Q.E. = 28.4 mils (1.60°).

Table A-1. UTPBS Test Data (15-m Impact Dispersion), Single E-Type Silhouette (continued)

ID No.	Project Type No.	Tube No., Serial No.	Mass (g)	M_v (ft/s)	Impact Location (Relative to Center of Mass)		
					Horizontal (in)	Vertical (in)	Hit Silhouette
4-10	4	2,2	8.12	210	0.5	-12.25	Yes
4-11	4	2,3	8.1	206	-2.5	-13.75	Yes
4-12	4	2,4	8.14	211	-3	-13.75	Yes
4-13	4	2,5	8.09	210	-3.25	-12.625	Yes
4-14	4	2,6	8.13	207	-1.75	-15.125	Yes
4-15	4	2,7	8.14	209	-2.5	-13.75	Yes
Average			8.12	210.33			
Std Dev			0.02	2.92			
Test Date: 3/19/98							
5-1	5	1,2	6.2	257	-0.5	-10	Yes
5-2	5	1,3	6.21	249	-2.25	-14.375	Yes
5-3	5	1,4	6.21	249	1	-12	Yes
5-4	5	1,5	6.2	255	2.75	-14	Yes
5-5	5	1,6	6.09	254	-3.5	-10	Yes
5-6	5	1,7	6.22	250	5.25	-9.75	Yes
5-7	5	1,8	6.18	252	4	-10	Yes
5-8	5	1,9	6.18	251	1.5	-9.25	Yes
5-9	5	1,10	6.2	253	-2.75	-12.25	Yes
5-10	5	2,1	6.16	260	-2	-11.5	Yes
5-11	5	2,2	6.21	250	-4.25	-9	Yes
5-12	5	2,3	6.25	250	0	-8.25	Yes
5-13	5	2,4	6.2	252	3	-8.25	Yes
5-14	5	2,5	6.02	258	-0.5	-10	Yes
5-15	5	2,6	6.19	256	0	-6.38	Yes
Average			6.18	253.07			
Std Dev			0.06	3.47			

NOTE: Barrel boresighted directly at target center of mass, Q.E. = 28.4 mils (1.60°).

Table A-2. UTPBS Test Data (30-m Impact Dispersion), Single E-Type Silhouette

ID No.	Project Type No.	Tube No., Serial No.	Mass (g)	M_v (ft/s)	Impact Location (Relative to Center of Mass)		
					Horizontal (in)	Vertical (in)	Hit Silhouette
Test Date: 3/19/98							
1-1	1	2,8	6.05	252	-13.5	-4.5	No
1-2	1	2,9	6.05	255	0.5	-2.5	Yes
1-3	1	2,10	6.05	251	10.5	2.25	No
1-4	1	3,1	6.03	247	9.75	-26.625	No
1-5	1	3,2	6.04	247	-4.5	7	Yes
1-6	1	3,3	6.07	247	-5.375	3.25	Yes
1-7	1	3,4	6.09	245	-7.375	1.5	Yes
1-8	1	3,5	6.08	248	0.625	-3.125	Yes
1-9	1	3,6	6.07	250	2.875	2.375	Yes
1-10	1	3,7	6.08	251	5.25	18.25	No
1-11	1	3,8	6.07	245	-35.25	5.5	Yes
1-12	1	3,9	6.12	249	-7.25	1.25	Yes
1-13	1	3,10	6.07	247	-2.25	-3	Yes
1-14	1	4,1	6.07	253	-5.5	0.875	Yes
1-15	1	4,2	6.07	248	22	35.75	No
Average			6.07	249.00			
Std Dev			0.02	2.93			
Test Date: 3/19/98							
2-1	2	2,6	6.01	221	11.5	-19.5	No
2-2	2	2,7	6.01	252	-10.125	0	No
2-3	2	2,8	6.01	252	-46	-14.5	No
2-4	2	2,9	6.01	257	15.25	0.75	No
2-5	2	2,10	6.01	255	11.125	-11	No
2-6	2	3,1	5.86	259	-25	-3.5	No
2-7	2	3,2	6.03	248	-21	-17	No
2-8	2	3,3	6.03	254	-9.5	-1.875	No
2-9	2	3,4	5.87	255	-34	-9.25	No
2-10	2	3,5	6.04	259	-10.25	-7.75	No
2-11	2	3,6	6.03	250	-36.25	-4.5	No
2-12	2	3,7	6.04	247	-6	-7.5	Yes
2-13	2	38	6.02	246	6.125	4.5	Yes

NOTE: Gun barrel boresighted 36 in above target center of mass, Q.E.= 45.3 mils (2.55°).

Table A-2. UTPBS Test Data (30-m Impact Dispersion), Single E-Type Silhouette (continued)

ID No.	Project Type No.	Tube No., Serial No.	Mass (g)	M_v (ft/s)	Impact Location (Relative to Center of Mass)		
					Horizontal (in)	Vertical (in)	Hit Silhouette
2-14	2	3,9	5.8	254	-11.375	-22.25	No
2-15	2	3,10	6.03	258	-3.875	-3	Yes
Average			5.99	251.13			
Std Dev			0.08	9.32			
Test Date: 3/19/98							
3-1	3	2,7	8.09	217	-7	-25.5	No
3-2	3	2,8	8.1	203	-9	-18.5	Yes
3-3	3	2,9	8.09	198	-15.75	-44	No
3-4	3	2,10	8.09	214	7.875	-24	No
3-5	3	3,1	7.98	199	-8.5	-19.375	Yes
2-6	3	3,2	8.07	199	-3.5	-20.5	Yes
3-7	3	3,3	8.09	200	-8	-21.125	No
3-8	3	3,4	8.07	199	18.5	-32.375	No
3-9	3	3,5	8.08	202	0	-20.375	Yes
3-10	3	3,6	7.99	209	11.5	-25.5	No
3-11	3	3,7	8.08	196	-16	-30.25	No
3-12	3	3,8	8.22	198	10.125	-33.375	No
3-13	3	3,9	8.08	201	-4.25	-20.75	Yes
3-14	3	3,10	8.05	202	-9	-22.5	No
3-15	3	4,1	8.11	202	-13.25	-26.75	No
Average			8.08	202.60			
Std Dev			0.05	6.06			
Test Date: 3/19/98							
4-1	4	2,8	8.12	227	12.5	-15.25	No
4-2	4	2,9	8.13	214	-13	-16.5	No
4-3	4	2,10	8.1	216	-3.5	-9.75	Yes
4-4	4	3,1	8.12	225	8.125	-14.5	Yes
4-5	4	3,2	8.14	220	-1.25	-3.125	Yes
4-6	4	3,3	8.13	222	5	-15.125	Yes
4-7	4	3,4	7.88	222	14.125	-11.25	No
4-8	4	3,5	8.06	221	7	-14.25	Yes
4-9	4	36	8.1	219	-11.5	-15.5	No

NOTE: Gun barrel boresighted 36 in above target center of mass, Q.E.= 45.3 mils (2.55°).

Table A-2. UTPBS Test Data (30-m Impact Dispersion), Single E-Type Silhouette (continued)

ID No.	Project Type No.	Tube No., Serial No.	Mass (g)	M_v (ft/s)	Impact Location (Relative to Center of Mass)		
					Horizontal (in)	Vertical (in)	Hit Silhouette
4-10	4	37	8.13	221	13.125	-19	No
4-11	4	38	8.12	228	13.125	-5.25	No
4-12	4	3,9	7.93	221	5.75	-5.75	Yes
4-13	4	3,10	8.12	228	1.375	-6.75	Yes
4-14	4	4,1	8.03	230	-9	-3.25	Yes
4-15	4	4,2	8.14	227	-7.5	-16	Yes
Average			8.08	222.73			
Std Dev			0.08	4.65			
Test Date: 3/19/98							
5-1	5	3,2	6.16	257	2.25	1.875	Yes
5-2	5	3,3	6.17	248	-3.75	-12.75	Yes
5-3	5	3,4	6.12	242	11	-20.125	No
5-4	5	3,5	6.22	241	7.375	-8.5	Yes
5-5	5	3,6	6.24	245	9.875	-10	Yes
5-6	5	3,7	6.15	245	-2.25	-10	Yes
5-7	5	3,8	6.15	245	-36	-31.5	No
5-8	5	3,9	6.22	249	-4	-3.25	Yes
5-9	5	3,10	6.21	254	-1.875	-2.75	Yes
5-10	5	4,1	6.03	249	2.25	-3.5	Yes
5-11	5	4,2	6.17	248	-4	1.5	Yes
5-12	5	4,3	6.16	249	-2.5	-9.75	Yes
5-13	5	4,4	6.22	246	-18.625	5	No
5-14	5	4,5	6.23	243	-3.75	24.5	No
5-15	5	4,6	6.19	258	-4.75	-4.5	Yes
Average			6.18	247.93			
Std Dev			0.05	5.08			

NOTE: Gun barrel boresighted 36 in above target center of mass, Q.E.= 45.3 mils (2.55°).

Table A-3. UTPBS Test Data (45-m Impact Dispersion), Single E-Type Silhouette

ID No.	Project Type No.	Tube No., Serial No.	Mass (g)	M_v (ft/s)	Impact Location (Relative to Center of Mass)		
					Horizontal (in)	Vertical (in)	Hit Silhouette
Test Date: 3/20/98							
1-1	1	4,3	6.06	259	5	-17.125	No
1-2	1	4,4	6.07	260	8.25	12.125	No
1-3	1	4,5	6.07	269	Missed Target	Missed Target	No
1-4	1	4,6	6.09	264	13	36	Yes
1-5	1	4,7	6.06	257	15.5	-8	No
1-6	1	4,8	6.07	259	8.25	-9	Yes
1-7	1	4,9	6.06	269	19	27.625	No
1-8	1	4,10	6.06	264	-37	9.25	No
1-9	1	5,1	6.08	264	-6.875	32.25	No
1-10	1	5,2	6.06	262	12.125	22	No
1-11	1	5,3	6.08	257	6.25	20.875	No
1-12	1	5,4	6.08	257	28.5	28.25	No
1-13	1	5,5	6.09	257	-1.5	-3.5	Yes
1-14	1	5,6	6.09	255	-15.5	24	No
1-15	1	5,7	6.09	262	0	7.625	Yes
Average			6.07	261.00			
Std Dev			0.01	4.36			
Test Date: 3/20/98							
2-1	2	4,1	6	262	10.25	18	No
2-2	2	4,2	6.02	233	-4.5	-3	Yes
2-3	2	4,3	6.02	241	-10.75	4.75	No
2-4	2	4,4	6.04	242	9.5	2.5	Yes
2-5	2	4,5	6.03	244	16.25	-25.75	No
2-6	2	4,6	6.02	242	-40.75	-30.25	No
2-7	2	4,7	6.01	241	-11	-4.5	No
2-8	2	4,8	6.03	244	-27.5	-24	No
2-9	2	4,9	6.01	241	-41.25	-31.25	No
2-10	2	4,10	6.02	243	-12.5	-9.5	No
2-11	2	5,1	6.03	240	12.5	-22.5	No
2-12	2	5,2	6	240	Missed Target	Missed Target	No
2-13	2	53	6.03	240	42.25	0	No

NOTE: Gun barrel boresighted 72 in above target center of mass, Q.E. = 50.8 mils (2.86°).

Table A-3. UTPBS Test Data (45-m Impact Dispersion), Single E-Type Silhouette (continued)

ID No.	Project Type No.	Tube No., Serial No.	Mass (g)	M_v (ft/s)	Impact Location (Relative to Center of Mass)		
					Horizontal (in)	Vertical (in)	Hit Silhouette
2-14	2	5,4	5.85	245	-28.25	-35	No
2-15	2	5,5	6.05	237	-8.75	9.5	No
Average			6.01	242.33			
Std Dev			0.05	6.20			
Test Date: 3/20/98							
3-1	3	4,3	8.07	220	-0.5	-23.125	No
3-2	3	4,4	7.99	222	36.75	-6.5	No
3-3	3	4,5	8.09	220	33	-1	No
3-4	3	4,6	8.05	216	22.625	-7	No
3-5	3	4,7	8.09	225	18.5	4.625	No
2-6	3	4,8	8.02	223	-7	-12.25	Yes
3-7	3	4,9	7.96	225	1.5	8.875	Yes
3-8	3	4,10	8.05	220	-59.5	-35.25	No
3-9	3	5,1	8.02	229	-15.5	28.5	No
3-10	3	5,2	8.07	224	5.75	-1	Yes
3-11	3	5,3	8.04	227	35	5	No
3-12	3	5,4	8.07	221	-44.5	-22.75	No
3-13	3	5,5	7.98	226	-23.375	-7	No
3-14	3	5,6	8.1	221	Missed Target	Missed Target	No
3-15	3	5,7	8.14	215	-3.5	-3	Yes
Average			8.05	222.27			
Std Dev			0.05	3.88			
Test Date: 3/20/98							
4-1	4	4,9	8.11	225	10.5	-1.5	No
4-2	4	4,10	8.13	224	-2.75	1.25	Yes
4-3	4	5,1	8.14	223	9	2.625	Yes
4-4	4	5,2	8.11	229	-15.25	6.125	No
4-5	4	5,3	8.09	220	-33.25	-31.25	No
4-6	4	5,4	7.96	222	1.625	-7	Yes
4-7	4	5,5	8.14	218	-42.5	-14.5	No
4-8	4	56	8.07	220	-11.5	-15.75	No

NOTE: Gun barrel boresighted 72 in above target center of mass, Q.E. = 50.8 mils (2.86°).

Table A-3. UTPBS Test Data (45-m Impact Dispersion), Single E-Type Silhouette (continued)

ID No.	Project Type No.	Tube No., Serial No.	Mass (g)	M_v (ft/s)	Impact Location (Relative to Center of Mass)		
					Horizontal (in)	Vertical (in)	Hit Silhouette
4-9	4	5,7	8.11	217	-6.25	-1.5	Yes
4-10	4	5,8	8.06	219	13	-11	No
4-11	4	5,9	8.12	221	6.75	-5	Yes
4-12	4	5,10	8.17	219	-12	-2	No
4-13	4	6,1	8.09	219	-42.75	-20.25	No
4-14	4	6,2	8.12	217	21.5	-14.875	No
4-15	4	6,3	8.04	219	-9.75	-19.5	No
Average			8.10	220.80			
Std Dev			0.05	3.30			
Test Date: 3/20/98							
5-1	5	4,7	5.97	242	-8.25	3.5	Yes
5-2	5	4,8	6.2	242	-16	0	No
5-3	5	4,9	5.99	241	12.5	-9	No
5-4	5	4,10	6.19	238	20.25	2.5	No
5-5	5	5,1	6.21	241	-4	-1	Yes
5-6	5	5,2	6.23	237	-7.75	-9.75	Yes
5-7	5	5,3	6.24	232	-2.5	-7	Yes
5-8	5	5,4	5.96	229	-7.75	-9.75	Yes
5-9	5	5,5	5.95	217	3	-29	No
5-10	5	6,1	6.11	178	Missed Target	Missed Target	No
5-11	5	6,2	6.16	203	5.5	-41.5	No
5-12	5	6,3	6.18	259	16.5	19.25	No
5-13	5	6,4	6.2	257	-18.5	-2.5	No
5-14	5	6,5	6.22	261	0.5	4	Yes
5-15	5	6,6	6.14	257	-3	4.5	Yes
Average			6.13	235.60			
Std Dev			0.11	22.42			

NOTE: Gun barrel boresighted 72 in above target center of mass, Q.E. = 50.8 mils (2.86°).

Table A-4. UTPBS Test Data (60-m Impact Dispersion), Three E-Type Silhouettes (Side by Side)

ID No.	Project Type No.	Tube No., Serial No.	Mass (g)	M_v (ft/s)	Impact Location		
					Horizontal (in)	Vertical (in)	Hit Silhouette
Test Date: 3/20/98							
1-1	1	5,8	6.07	260	40	-39	No
1-2	1	5,9	6.09	262	10	-3	Yes
1-3	1	5,10	6.08	268	Missed Target	Missed Target	No
1-4	1	6,1	6.1	256	-5	-32	No
1-5	1	6,2	6.09	258	12.5	15	No
1-6	1	6,3	6.09	264	mt	mt	No
1-7	1	6,4	6.1	260	-4.5	42.5	No
1-8	1	6,5	6.14	259	Missed Target	Missed Target	No
1-9	1	6,6	6.1	253	1	-34	No
1-10	1	6,7	6.09	263	-55.5	-31	No
1-11	1	6,8	6.09	261	9	57	No
1-12	1	6,9	6.09	263	Missed Target	Missed Target	No
1-13	1	6,10	6.11	264	-6	-13.5	Yes
1-14	1	7,1	6.1	258	-13	19.5	Yes
1-15	1	7,2	6.1	262	2	-45	No
Average			6.10	260.73			
Std Dev			0.02	3.67			
Test Date: 3/20/98							
2-1	2	5,6	5.99	263	35	-27.5	No
2-2	2	5,7	6.03	261	-6	-23.5	No
2-3	2	5,8	6.01	257	61.5	-34.5	No
2-4	2	5,9	6.03	259	mt	mt	No
2-5	2	6,1	6.02	261	-16.5	-20.5	No
2-6	2	6,2	6.03	260	22.5	-32	No
2-7	2	6,3	6.03	255	Missed Target	Missed Target	No
2-8	2	6,4	6.01	254	-51.5	-23	No
2-9	2	6,5	6.01	261	24.5	-28	No
2-10	2	6,6	6.04	261	9.5	-32.5	No
2-11	2	6,7	6.03	254	60	-29.5	No
2-12	2	68	6.03	256	Missed Target	Missed Target	No

NOTE: Gun barrel boresighted 144 in above target center of mass, Q.E. = 69.1 mils (3.89°).

Table A-4. UTPBS Test Data (60-m Impact Dispersion), Three E-Type Silhouettes (Side by Side) (continued)

ID No.	Project Type No.	Tube No., Serial No.	Mass (g)	M_v (ft/s)	Impact Location		
					Horizontal (in)	Vertical (in)	Hit Silhouette
2-13	2	6,9	6.03	254	Missed Target	Missed Target	No
2-14	2	6,10	6.04	258	60	-38	No
2-15	2	7,1	6.02	258	30	-10	Yes
Average			6.02	258.13			
Std Dev			0.01	3.02			
Test Date: 3/23/98							
3-1	3	5,8	8.08	190	Missed Target	Missed Target	No
3-2	3	5,9	8.11	174	Missed Target	Missed Target	No
3-3	3	5,10	8.08	168	Missed Target	Missed Target	No
3-4	3	6,1	8.07	181	Missed Target	Missed Target	No
Note: Regulator could not be adjusted, internal regulator workings came out instead of end cap.							
Average			8.08	178.25			
Std Dev			0.02	9.46			
Test Date: 3/31/98							
3-1	3	8,4	8.06	243	35.5	-7	No
3-2	3	8,5	8.09	249	Missed Target	Missed Target	No
3-3	3	8,6	8.1	251	55.25	-30	No
3-4	3	8,7	8.08	238	Missed Target	Missed Target	No
3-5	3	8,8	8.08	244	Missed Target	Missed Target	No
3-6	3	8,9	8.08	243	-5.5	-34	No
3-7	3	8,10	8.09	246	2	-37	No
3-8	3	9,1	8.07	252	Missed Target	Missed Target	No
3-9	3	9,2	8.04	248	-42	-34	No
3-10	3	9,3	8.09	246	25.5	10	Yes
3-11	3	9,4	8.04	248	-30	-39	No
3-12	3	9,5	8.1	253	-12	-21	No
3-13	3	9,6	8.11	259	-26.5	11	Yes
3-14	3	9,7	8.07	249	Missed Target	Missed Target	No
3-15	3	9,8	8.08	249	-52.5	-16	No
Average			8.08	247.87			
Std Dev			0.02	4.98			

NOTE: Gun barrel boresighted 144 in above target center of mass, Q.E. = 69.1 mils (3.89°).

Table A-4. UTPBS Test Data (60-m Impact Dispersion), Three E-Type Silhouettes (Side by Side) (continued)

ID No.	Project Type No.	Tube No., Serial No.	Mass (g)	M_v (ft/s)	Impact Location		
					Horizontal (in)	Vertical (in)	Hit Silhouette
Test Date: 3/31/98							
4-1	4	8,6	8.09	256	-37.5	-23	No
4-2	4	8,7	8.09	248	-27	-19.5	Yes
4-3	4	8,8	8.02	250	-5.75	-24.75	No
4-4	4	8,9	7.87	247	12	-30.5	No
4-5	4	8,10	8.13	245	10	-27.5	No
4-6	4	9,1	7.92	248	5.75	-21.75	No
4-7	4	9,2	8.09	255	-34.5	1.75	No
4-8	4	9,3	8.07	247	-30.75	-37.5	No
4-9	4	9,4	8.14	241	-16	-45	No
4-10	4	9,5	7.96	250	-25.5	-36	No
4-11	4	9,6	8.11	243	21	-47.5	No
4-12	4	9,7	7.79	254	1	-22.75	No
4-13	4	9,8	7.93	249	-13.75	-35.25	No
4-14	4	9,9	8.13	243	16.5	-44	No
4-15	4	9,10	8.13	242	Missed Target	Missed Target	No
Average			8.03	247.87			
Std Dev			0.11	4.66			
Test Date: 3/23/98							
5A-4	5	7,7	6.1	250	-12.5	-35.5	No
5A-5	5	7,8	6.08	258	8	-22	No
5A-6	5	7,9	6.18	256	-12.5	-30	No
5A-7	5	7,10	6.16	254	30	-24	No
5A-8	5	8,1	6.13	211	Missed Target	Missed Target	No
5A-9	5	8,2	6.18	248	Missed Target	Missed Target	No
5A-10	5	8,3	6.13	265	-4.5	-21	No
Average			5.38	218.33			
Std Dev			2.13	87.86			

NOTE: Gun barrel boresighted 144 in above target center of mass, Q.E. = 69.1 mils (3.89°).

Table A-5. UTPBS Test Data (75-m Impact Dispersion), Three E-Type Silhouettes (Side by Side)

ID No.	Project Type No.	Tube No., Serial No.	Mass (g)	M_v (ft/s)	Impact Location		
					Horizontal (in)	Vertical (in)	Hit Silhouette
Test Date: 3/22/98							
1-1	1	7,3	6.09	234	Missed Target	Missed Target	No
1-2	1	7,4	6.09	212	Missed Target	Missed Target	No
1-3	1	7,5	6.09	214	Missed Target	Missed Target	No
1-4	1	7,6	6.09	208	Missed Target	Missed Target	No
1-5	1	7,7	6.08	225	Missed Target	Missed Target	No
1-6	1	7,8 See note.	6.08	242	Missed Target	Missed Target	No
1-7	1	7,9	6.1	225	Missed Target	Missed Target	No
1-8	1	7,10	6.1	220	Missed Target	Missed Target	No
1-9	1	8,1	6.08	265	Missed Target	Missed Target	No
1-10	1	8,2	6.09	268	Missed Target	Missed Target	No
Average			6.09	231.30			
Std Dev			0.01	21.15			
Note: Had to take regulator apart to adjust velocity.							
Test Date: 3/23/98							
2-1	2	7,2	6.02	266	18.5	-13	Yes
2-2	2	7,3	6.03	255	-6.5	-32	No
2-3	2	7,4	6.03	257	-58	-31	No
2-4	2	7,5	6.02	263	-89	-22	No
2-5	2	7,6	6.04	253	-31	-4.5	Yes
2-6	2	7,7	6.03	255		Missed Target	No
2-7	2	7,8	6.02	261	8.5	-10	Yes
2-8	2	7,9	6.02	253	Missed Target	Missed Target	No
2-9	2	7,10	6.03	246	-14	89	No
2-10	2	8,1	6.03	248	Missed Target	Missed Target	No
Average			6.03	255.70			
Std Dev			0.01	6.31			
Test Date: 3/23/98							
3-1	3	62	8.09	225	19.5	-45.5	No
3-2	3	63	8.1	225	Missed Target	Missed Target	No

NOTE: Gun barrel boresighted 293.7 in above target center of mass, Q.E. = 101.0 mils (5.68°).

Table A-5. UTPBS Test Data (75-m Impact Dispersion), Three E-Type Silhouettes (Side by Side) (continued)

ID No.	Project Type No.	Tube No., Serial No.	Mass (g)	M_v (ft/s)	Impact Location		
					Horizontal (in)	Vertical (in)	Hit Silhouette
3-3	3	6,4	8.1	231	Missed Target	Missed Target	No
3-4	3	6,5	8.08	243	Missed Target	Missed Target	No
3-5	3	6,6	8.09	227	Missed Target	Missed Target	No
3-6	3	6,7	8.09	233	-15	0.5	Yes
3-7	3	6,8	8.16	227	Missed Target	Missed Target	No
3-8	3	6,9	8.03	228	Missed Target	Missed Target	No
3-9	3	6,10	8.03	239	-71	-31	No
3-10	3	7,1	8.09	240	-20.5	-1	Yes
Average			8.09	231.80			
Std Dev			0.04	6.66			
Test Date: 3/23/98							
4-1	4	6,4	8.06	243	-25.5	40	No
4-2	4	6,5	8.14	246	-25	22	No
4-3	4	6,6	8.05	246	-43.5	1/7.5	Yes
4-4	4	6,7	8.08	247	8	-3	No
4-5	4	6,8	8.1	241	26.5	51.5	No
4-6	4	6,9	8.14	245	-30.5	-11.5	Yes
4-7	4	6,10	8.09	249	13	57	No
4-8	4	7,1	8.12	239	81	40.5	No
4-9	4	7,2	7.98	246	26	17	Yes
4-10	4	7,3	8.11	234	Missed Target	Missed Target	No
Average			8.09	243.60			
Std Dev			0.05	4.48			
Test Date: 3/23/98							
5-1	5	8,4	6.08	271	Missed Target	Missed Target	No
5-2	5	8,5	6.17	258	51.5	-35	No
5-3	5	8,6	6.23	261	0	60	No
5-4	5	8,7	6.15	262	-9.5	45.5	No
5-5	5	8,8	6.2	253	20	-17.5	Yes
5-6	5	8,9	6.18	255	9	5	Yes
5-7	5	8,10	6.16	259	-31.5	-1.5	No

NOTE: Gun barrel boresighted 293.7 in above target center of mass, Q.E. = 101.0 mils (5.68°).

Table A-5. UTPBS Test Data (75-m Impact Dispersion), Three E-Type Silhouettes (Side by Side) (continued)

ID No.	Project Type No.	Tube No., Serial No.	Mass (g)	M_v (ft/s)	Impact Location		
					Horizontal (in)	Vertical (in)	Hit Silhouette
5-8	5	9,1	6.23	256	-16.5	-10	No
5-9	5	9,2	6.19	257	Missed Target	Missed Target	No
5-10	5	9,3	6.22	257	-2	-46	No
Average			6.18	257.50			
Std Dev			0.05	3.02			

NOTE: Gun barrel boresighted 293.7 in above target center of mass, Q.E. = 101.0 mils (5.68°).

Table A-6. UTPBS Test Data (100-m Impact Dispersion), Three E-Type Silhouettes (Side by Side)

ID No.	Project Type No.	Tube No., Serial No.	Mass (g)	M_v (ft/s)	Impact Location		
					Horizontal (in)	Vertical (in)	Hit Silhouette
Test Date: 3/23/98							
1-1	1	8,3	6.1	256	Missed Target	Missed Target	No
1-2	1	8,4	5.99	255	Missed Target	Missed Target	No
1-3	1	8,5	6.08	256	Missed Target	Missed Target	No
1-4	1	8,6	6.08	253	Missed Target	Missed Target	No
1-5	1	8,7	6.09	252	Missed Target	Missed Target	No
1-6	1	8,8	6.09	250	Missed Target	Missed Target	No
1-7	1	8,9	6.09	253	Missed Target	Missed Target	No
1-8	1	8,10	6.09	255	Missed Target	Missed Target	No
1-9	1	9,1	6.1	255	Missed Target	Missed Target	No
1-10	1	9,2	6.1	252	Missed Target	Missed Target	No
Average			6.08	253.70			
Std Dev			0.03	2.00			
Test Date: 3/23/98							
2-1	2	8,2	6.02	259	Missed Target	Missed Target	No
2-2	2	8,3	6.02	256	Missed Target	Missed Target	No
2-3	2	8,4	6.03	255	Missed Target	Missed Target	No
2-4	2	8,5	6.02	265	Missed Target	Missed Target	No
2-5	2	8,6	6.02	251	Missed Target	Missed Target	No
2-6	2	8,7	6.02	254	Missed Target	Missed Target	No
2-7	2	8,8	6.03	251	Missed Target	Missed Target	No
2-8	2	8,9	6	257	Missed Target	Missed Target	No
2-9	2	8,10	6.01	252	Missed Target	Missed Target	No
2-10	2	9,1	6.03	255	Missed Target	Missed Target	No
Average			6.02	255.50			
Std Dev			0.01	4.22			
Test Date: 3/23/98							
3-1	3	7,2	8.05	230	-12.5	-12.5	Yes
3-2	3	7,3	8.1	223	Missed Target	Missed Target	No
3-3	3	7,4	8.11	252	-32	63	No
3-4	3	7,5	8.12	243	Missed Target	Missed Target	No
3-5	3	7,6	8.19	238	40.5	-21.5	No
3-6	3	7,7	8.08	241	-33.5	7.5	No
3-7	3	7,8	8.18	233	16	-35	No
3-8	3	7,9	8.13	238	Missed Target	Missed Target	No

NOTE: Gun barrel boresighted 587.7 in above target center of mass, Q.E. = 151.0 mils (8.49°).

Table A-6. UTPBS Test Data (100-m Impact Dispersion), Three E-Type Silhouettes (Side by Side) (continued)

ID No.	Project Type No.	Tube No., Serial No.	Mass (g)	M_v (ft/s)	Impact Location		
					Horizontal (in)	Vertical (in)	Hit Silhouette
3-9	3	7,10	8.09	232	Missed Target	Missed Target	No
3-10	3	8,1	7.98	234	24	-33.5	No
Average			8.10	236.40			
Std Dev			0.06	7.96			
Test Date: 3/23/98							
4-1	4	7,4 See note.	8.13	173	Missed Target	Missed Target	No
4-2	4	7,5	8.12	243	Missed Target	Missed Target	No
4-3	4	7,6	8.14	244	-37	11	No
4-4	4	7,7	7.9	246	-62	5	No
4-5	4	7,8	8.02	250	Missed Target	Missed Target	No
4-6	4	8,1	8.13	265	Missed Target	Missed Target	No
4-7	4	8,2	8.11	242	-22	32	No
4-8	4	8,3	8.08	240	-56.5	3	No
4-9	4	8,4	8.06	238	-41	-15	No
4-10	4	8,5	7.97	236	65	-4	No
Average			8.07	237.70			
Std Dev			0.08	24.14			
Note: Projectile burst in barrel.							
Test Date: 3/23/98							
5-1	5	9,4	6.19	254	Missed Target	Missed Target	No
5-2	5	9,5	6.15	257	Missed Target	Missed Target	No
5-3	5	9,6	6.12	215	Missed Target	Missed Target	No
5-4	5	9,7	6.24	245	Missed Target	Missed Target	No
5-5	5	9,8	6.24	251	Missed Target	Missed Target	No
5-6	5	9,9	6.18	252	Missed Target	Missed Target	No
5-7	5	9,10	6.18	255	5.5	-45	No
5-8	5	10,1	6.12	256	Missed Target	Missed Target	No
5-9	5	10,2	6.18	252	Missed Target	Missed Target	No
5-10	5	10,3	6.22	245	Missed Target	Missed Target	No
Average			6.18	248.20			
Std Dev			0.04	12.37			

NOTE: Gun barrel boresighted 587.7 in above target center of mass, Q.E. = 151.0 mils (8.49°).

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Appendix B:

Radar Data

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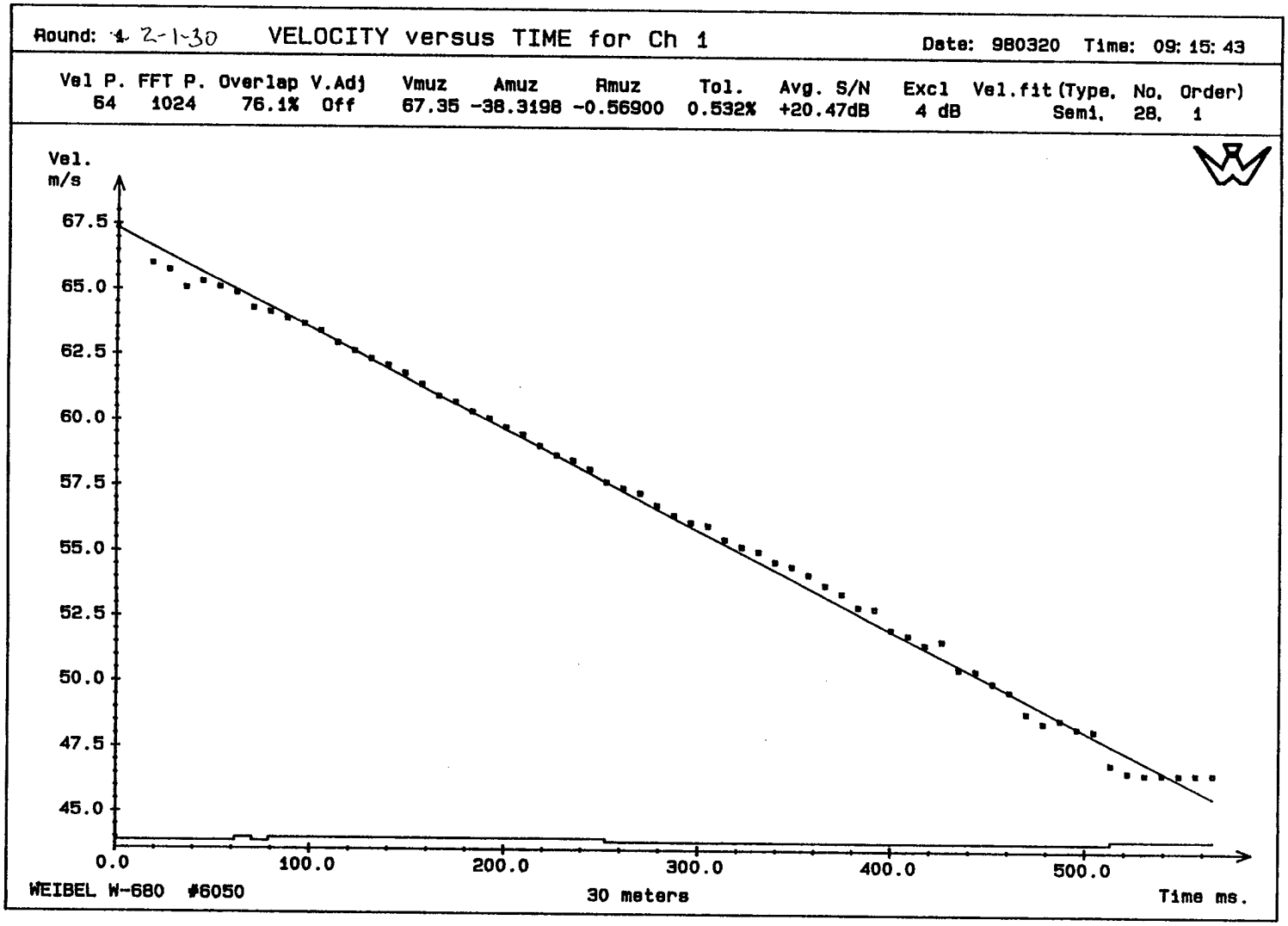

Figure B-1. Velocity vs. Time for Ch. 1.

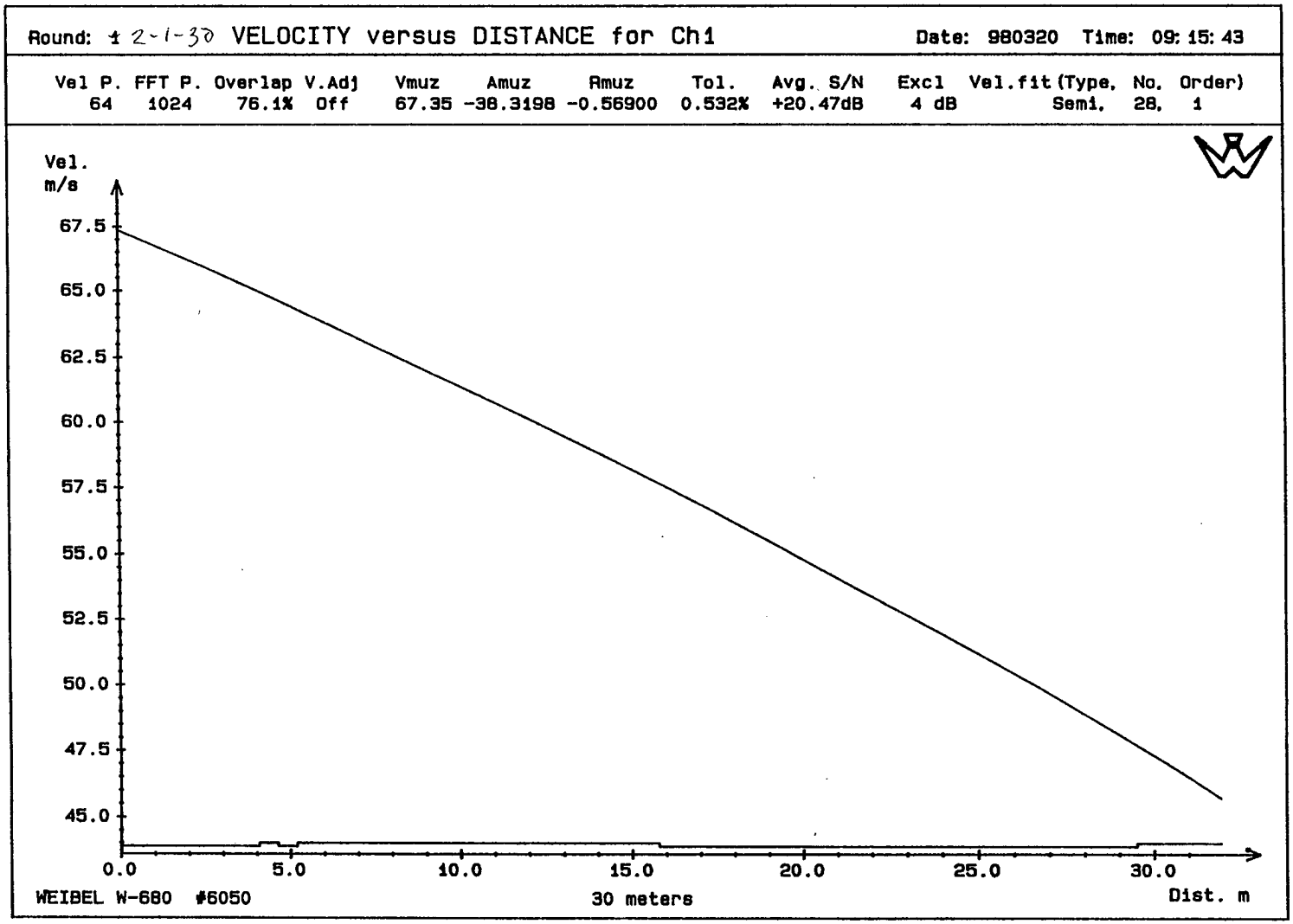

Figure B-2. Velocity vs. Distance for Ch. 1.

Appendix C:

Through-Barrel X-rays

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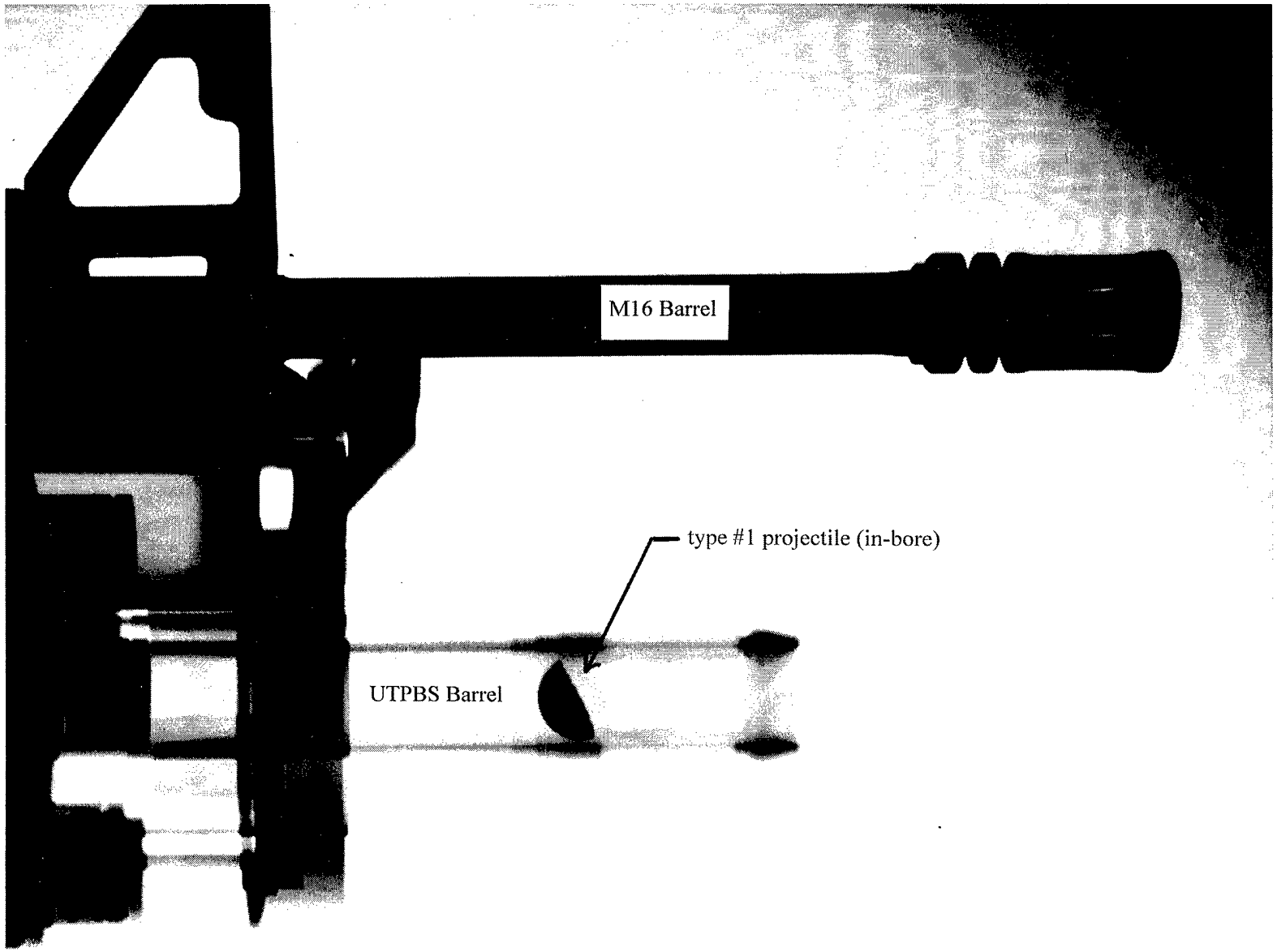

Figure C-1. Through Barrel X-rays for Type No. 1 Projectile.

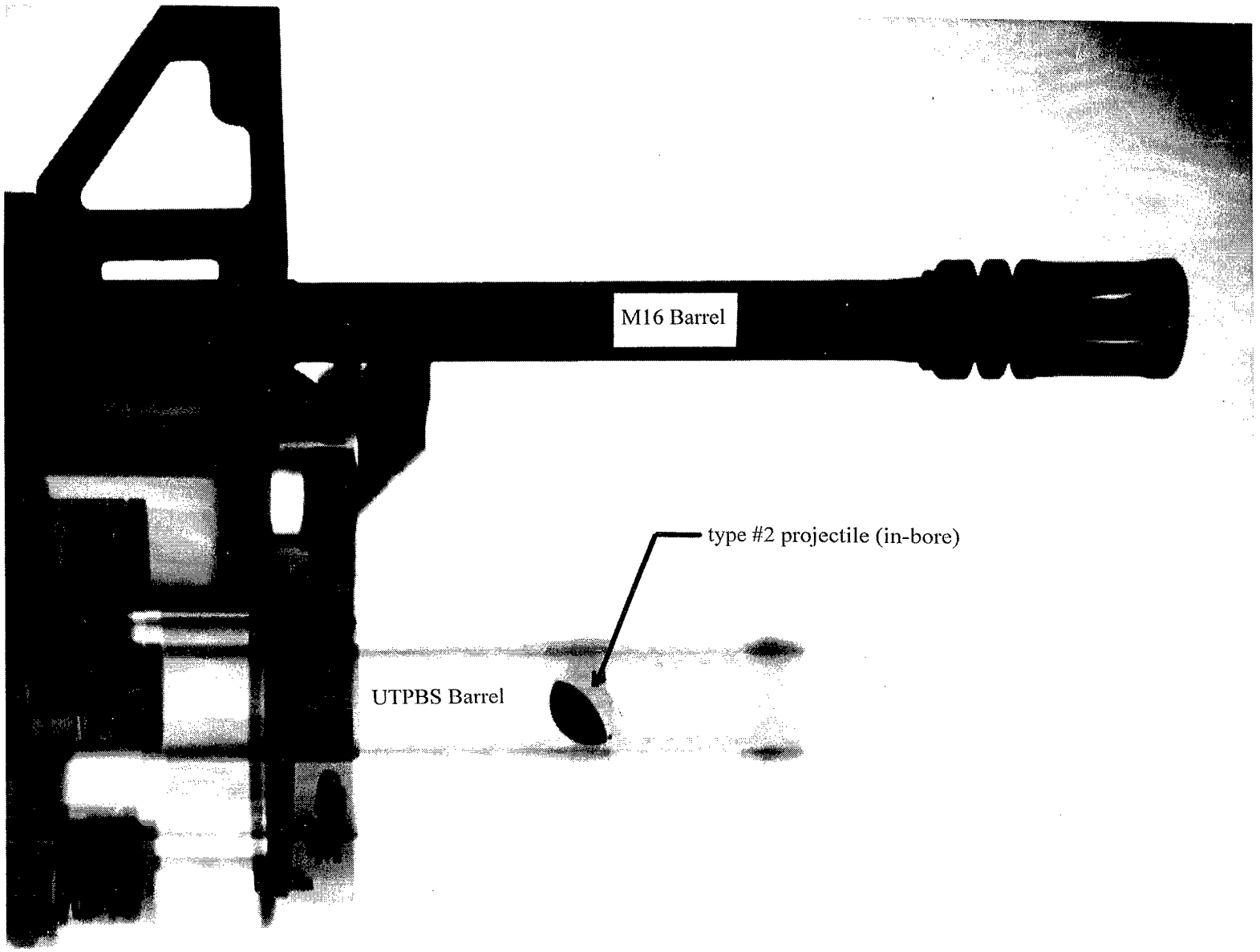

Figure C-2. Through Barrel X-rays for Type No. 2 Projectile.

Appendix D:

Vertical X-rays

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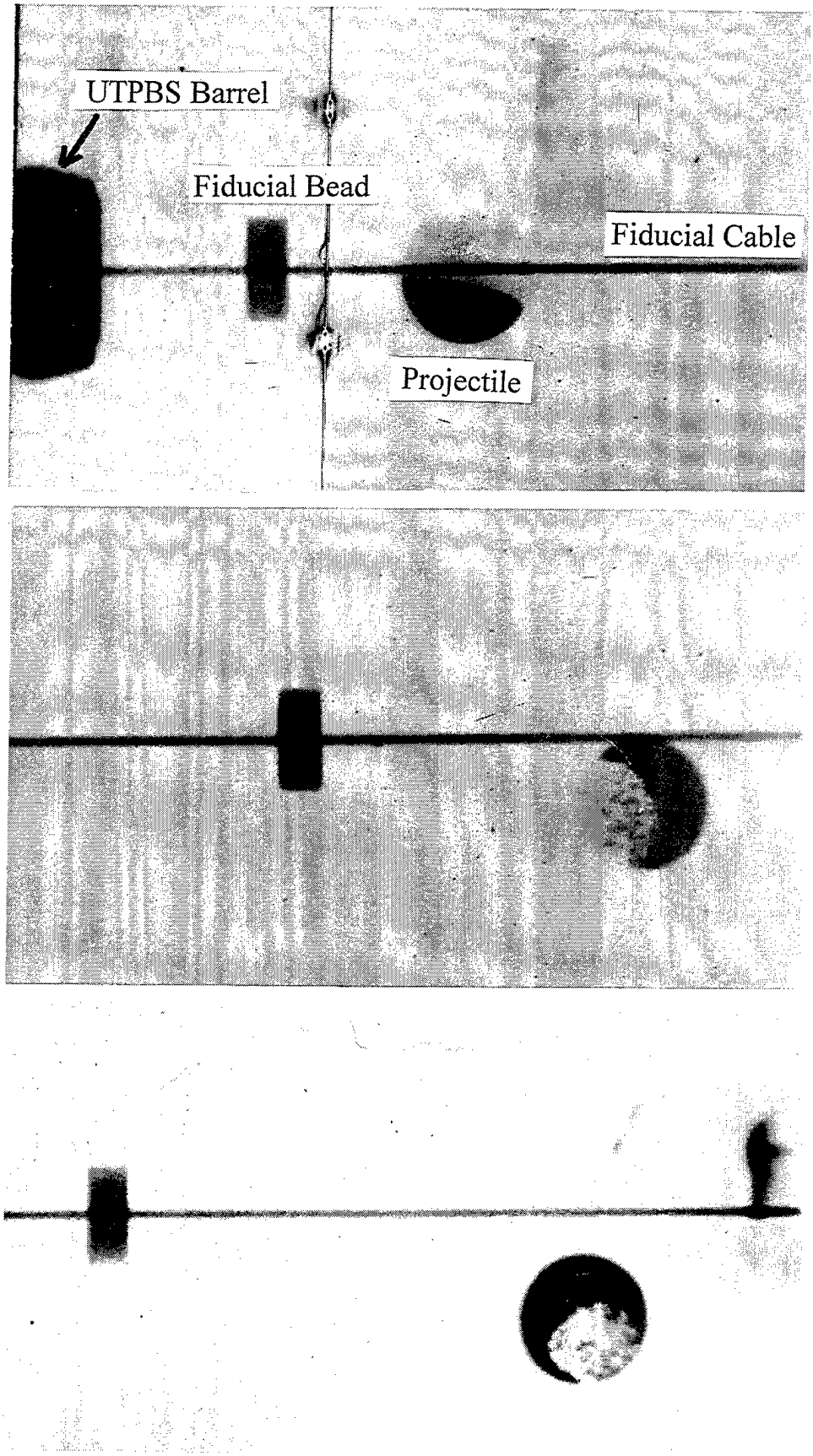

Figure D-1. Vertical X-rays From First Three Stations, Type No. 2.

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Appendix E:

Spark Shadowgraph

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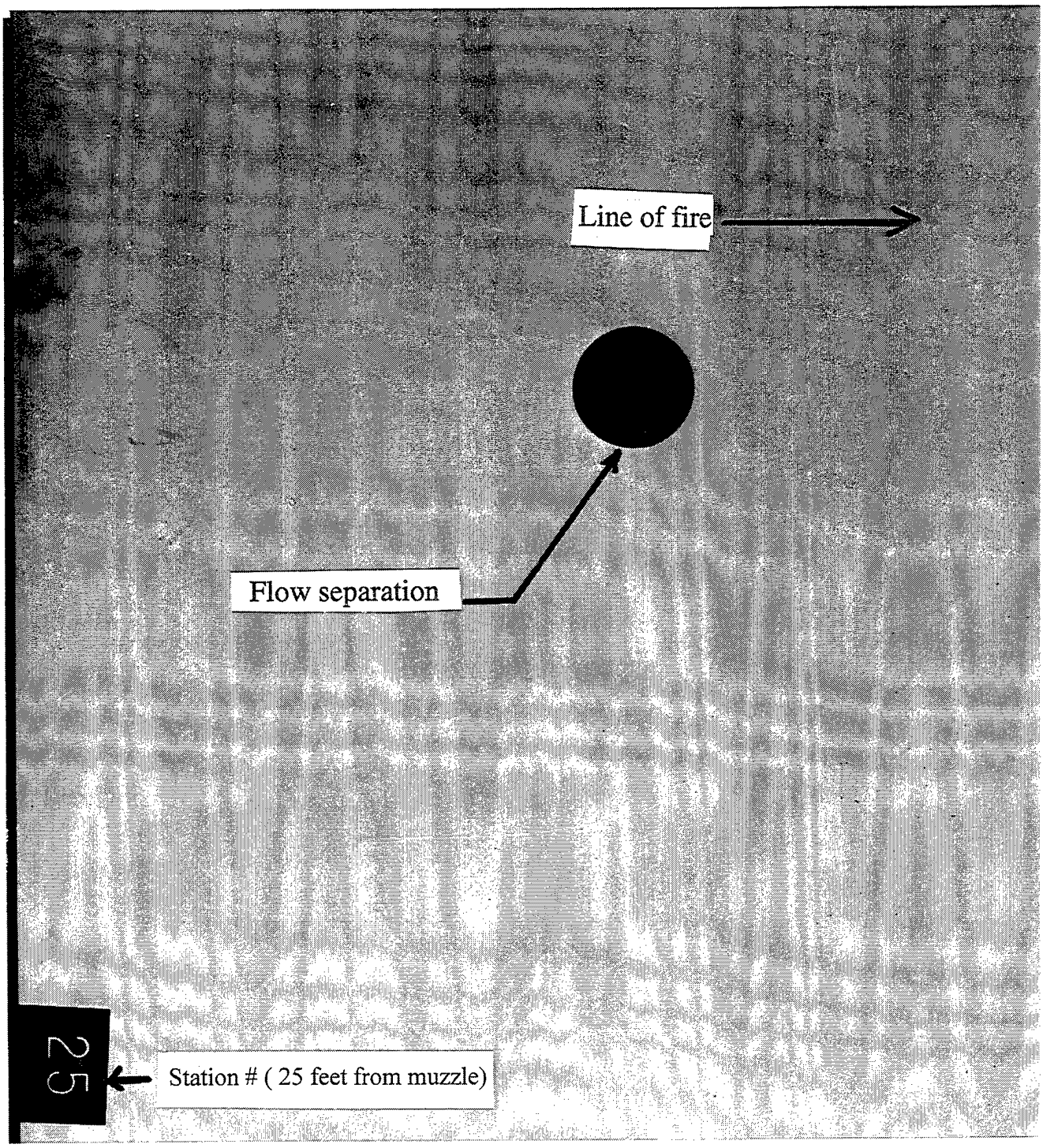

Figure E-1. Spark Shadowgraph of Type No. 1 Projectile, Vertical Film Plane.

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Appendix F:

Simulated Trajectories for 6-g and 8-g Projectiles

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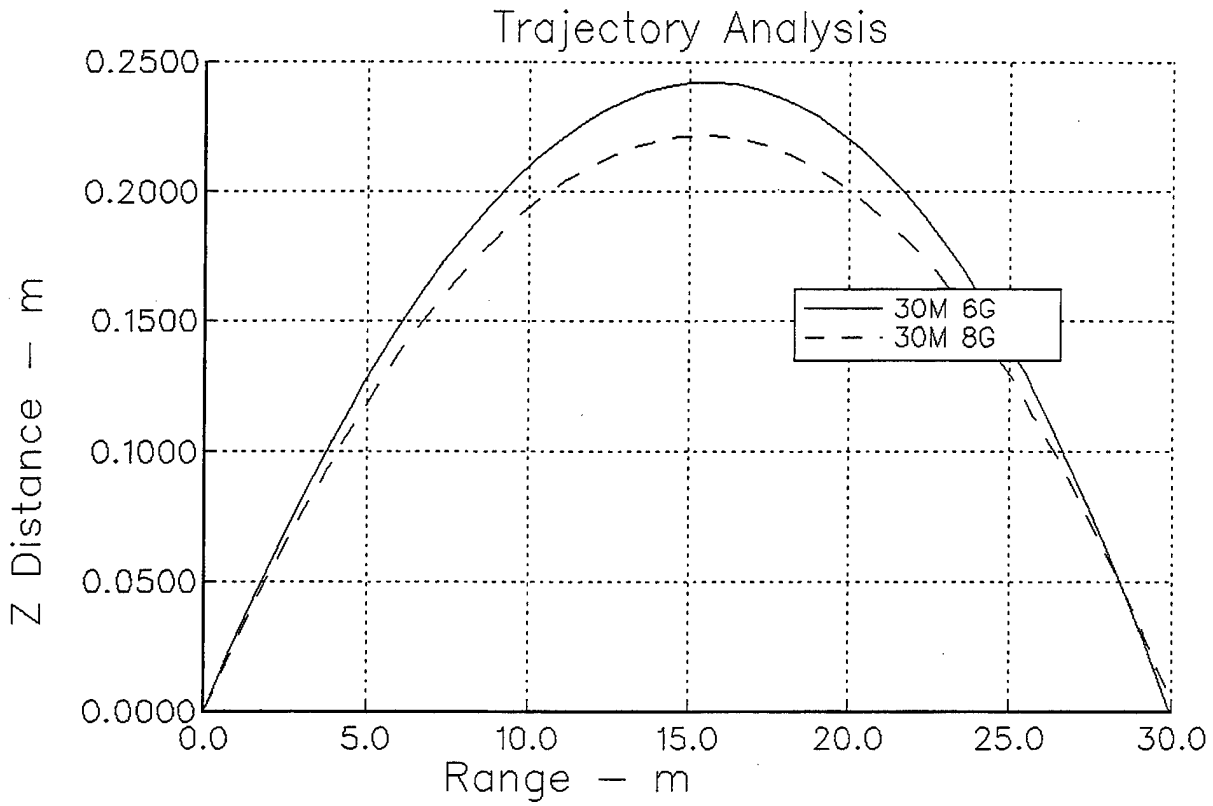

Figure F-1. Simulated Trajectories for 6-g and 8-g Projectiles, at 30-m Range.

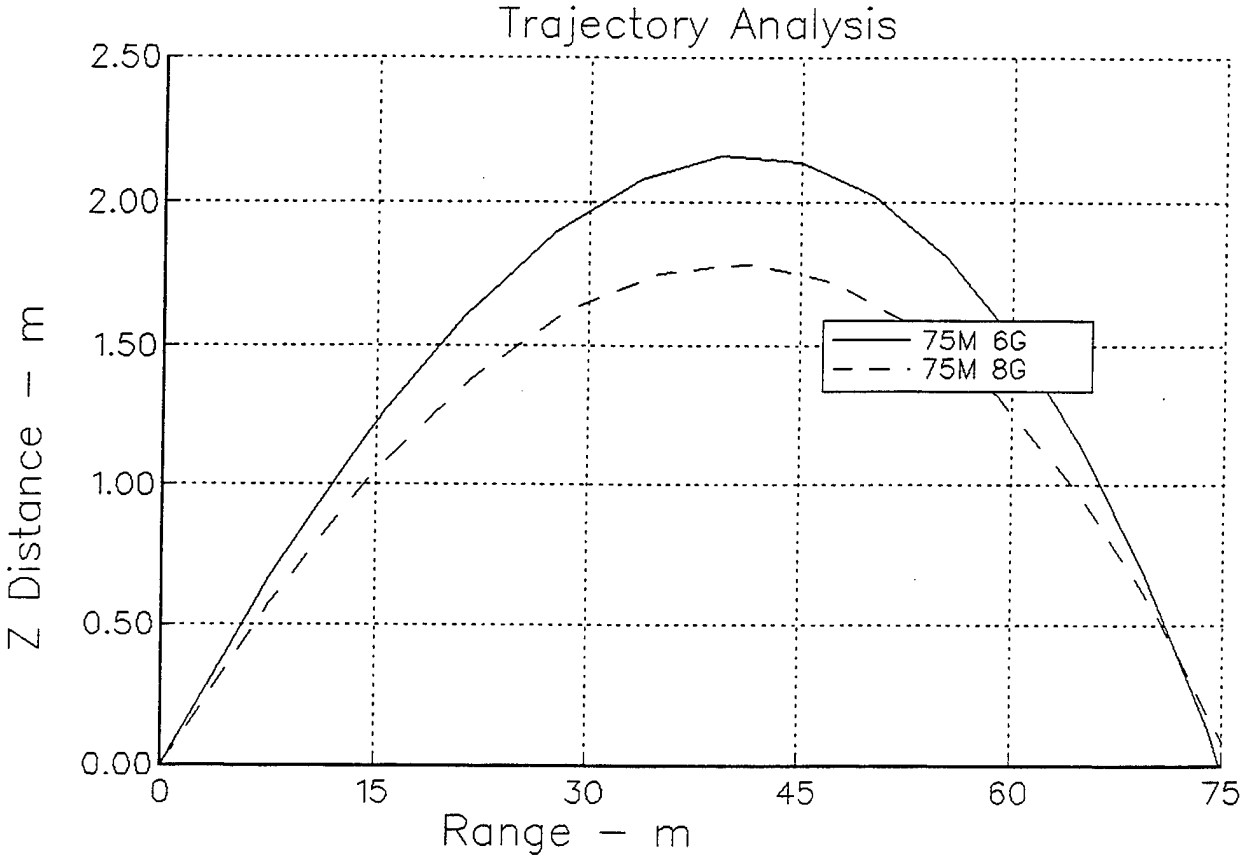

Figure F-2. Simulated Trajectories for 6-g and 8-g Projectiles, at 75-m Range.

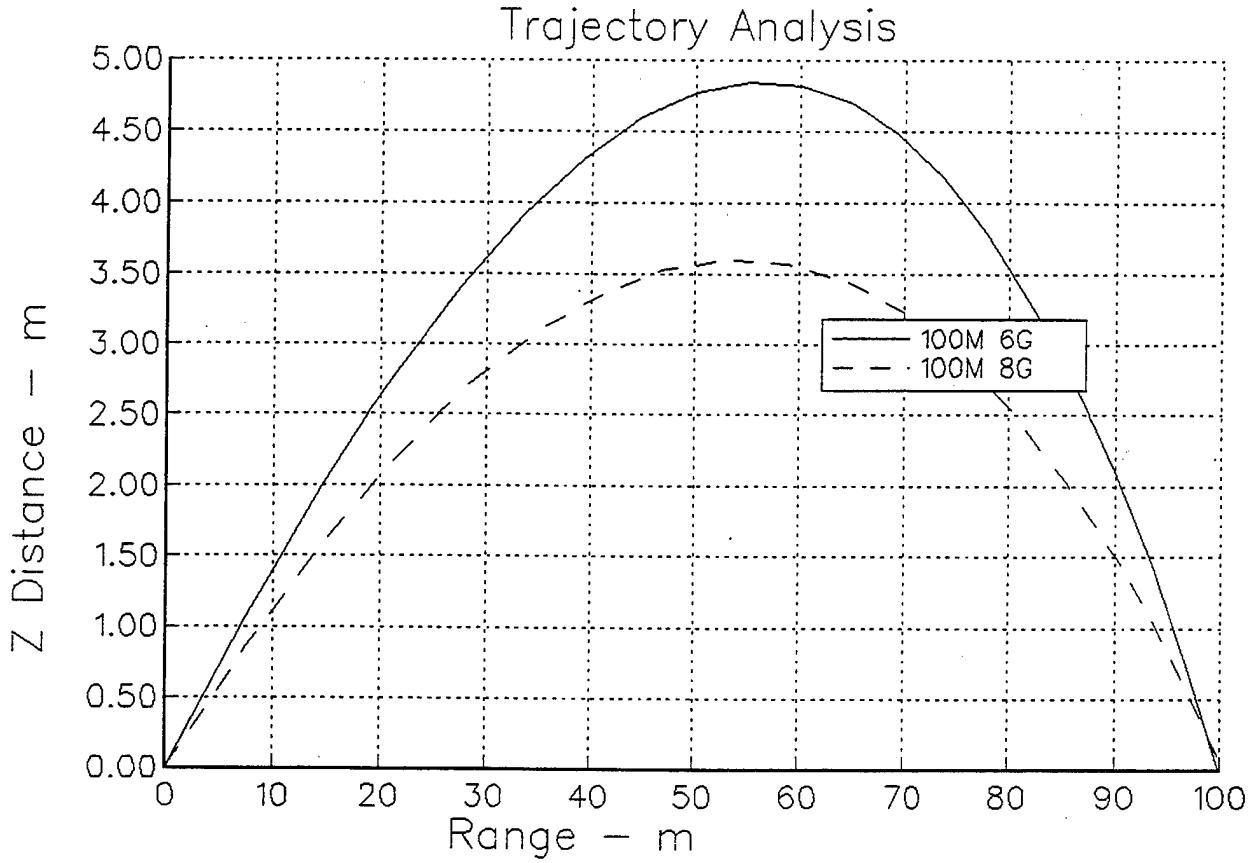

Figure F-3. Simulated Trajectories for 6-g and 8-g Projectiles, at 100-m Range.

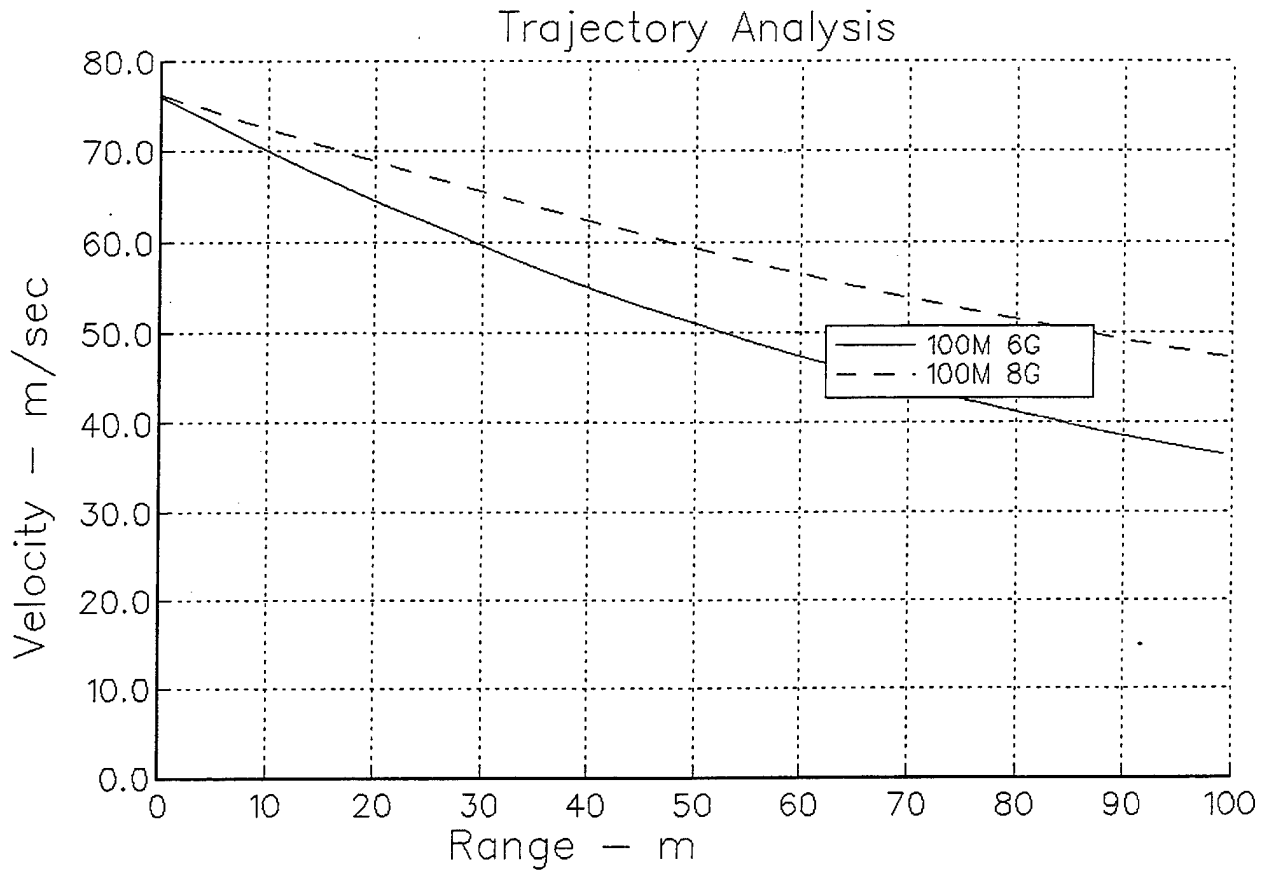

Figure F-4. Velocity Decay for 6-g and 8-g Projectiles, out to 100-m Range.

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ATTN: AMSRL-WM-BC
Aberdeen Proving Ground, MD 21005-5066

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13. ABSTRACT *(Maximum 200 words)*

This report contains data obtained while conducting a test of the Under-Barrel Tactical Paint Ball System (UTPBS). This testing was conducted by the U.S. Army Research Laboratory (ARL) upon the request of both the U.S. Army Armament Research, Development, and Engineering Center (ARDEC) and user representatives. The UTPBS device attaches under the barrel of either the M16 rifle or M4 carbine, similar to an M203. It consists of a trigger group and a central launch tube, which is surrounded by five rotating magazine tubes. A compressed gas bottle is located coaxial to the launch tube and supplies high-pressure gas for operation of the device. Five different types of projectiles were evaluated with the launcher. These were based upon a spherical, ruggedized paint ball with a hard plastic shell and various fills that contained bismuth powder and a combination of paint or water. The system was fired for target impact dispersion, launch dynamics, aerodynamics, and clay penetration. The ability of the weapon to target and hit a triple silhouette at 100 m was almost zero. To isolate the sources of trajectory deviation, a launch dynamics test was performed. A combination of x-rays and spark shadowgraphs revealed large transverse displacements immediately following launch. The case of this deviation was related to the shifting of the bismuth powder inside the projectile, thereby creating a mass asymmetry.

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5. Has the information in this report led to any quantitative savings as far as man-hours or dollars saved, operating costs avoided, or efficiencies achieved, etc? If so, please elaborate. _____

6. General Comments. What do you think should be changed to improve future reports? (Indicate changes to organization, technical content, format, etc.) _____

CURRENT ADDRESS

Organization

Name E-mail Name

Street or P.O. Box No.

City, State, Zip Code

7. If indicating a Change of Address or Address Correction, please provide the Current or Correct address above and the Old or Incorrect address below.

OLD ADDRESS

Organization

Name

Street or P.O. Box No.

City, State, Zip Code

(Remove this sheet, fold as indicated, tape closed, and mail.)

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